Hurricanes – A Science Primer

What is a Hurricane?; Intensity and Track Considerations; Landfall/Post-Landfall Impacts

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National Weather Service – Wakefield, VA

Hurricanes – A Science Primer

- What Will be Covered
  - Hurricane Background – What is a Hurricane
  - Hurricane Movement and Intensity
  - Hurricane Impacts
    - Storm Surge
    - Wind
    - Rainfall
    - Tornadoes
- What Will Not be Covered
  - HURREVAC and SLOSH

What is a Hurricane?

- An Area of Low Pressure that develops in the tropics/subtropics and has winds 74+ mph

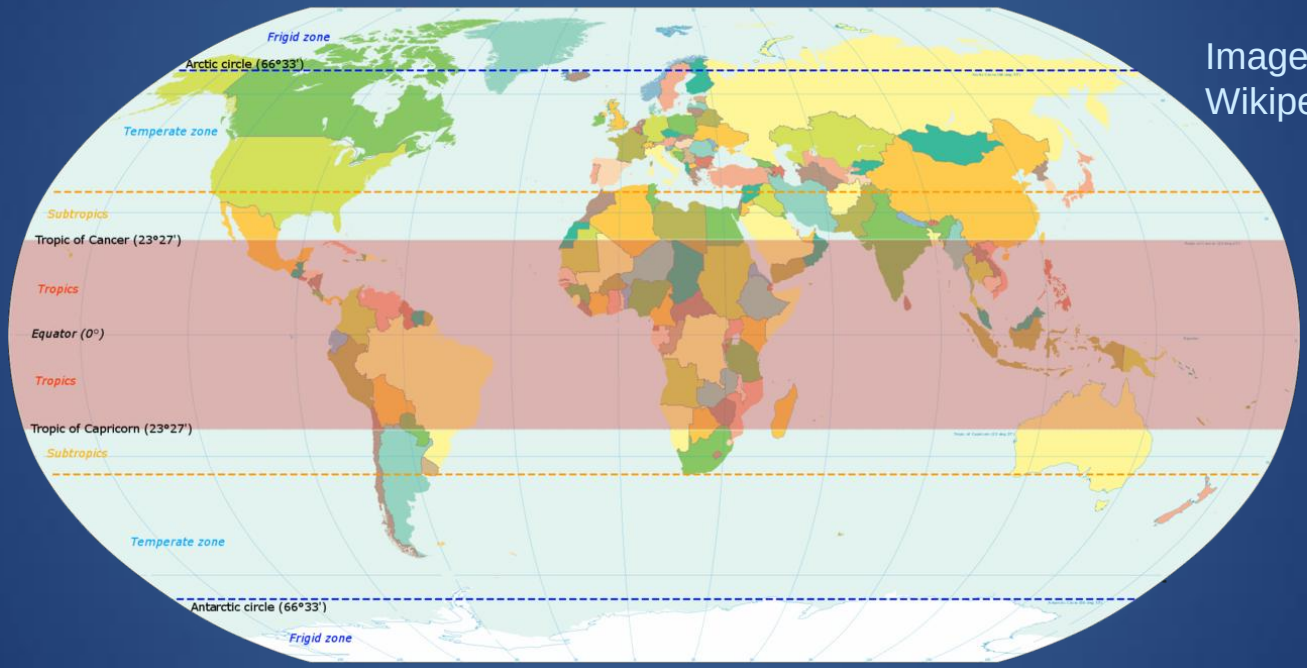
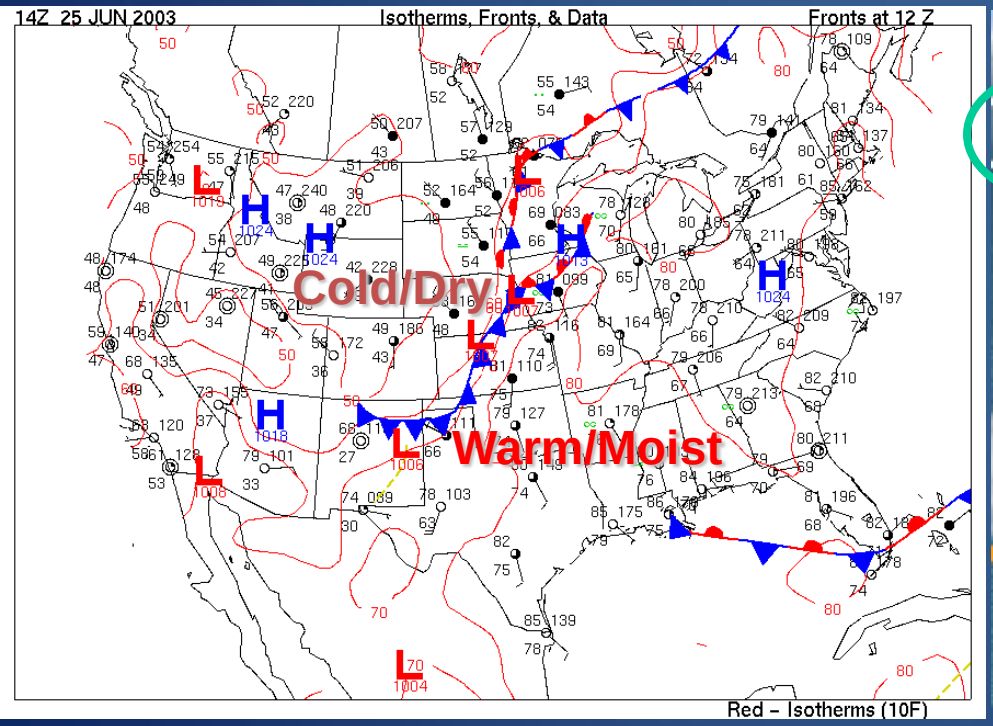


Image from Wikipedia

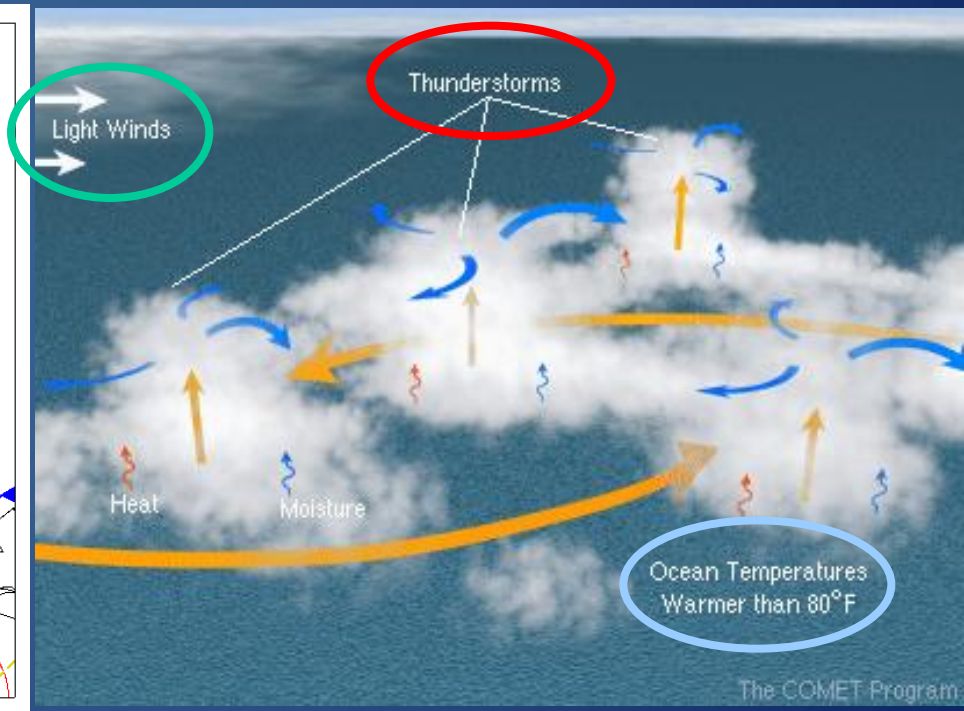
- Also Known as
  - Typhoons (Western Pacific)
  - Cyclones (Indian Ocean)
- Development Sequence – Tropical Depression, Tropical Storm*, Hurricane

Hurricanes – The Basics

Hurricanes are, from a storm perspective, unique in nature



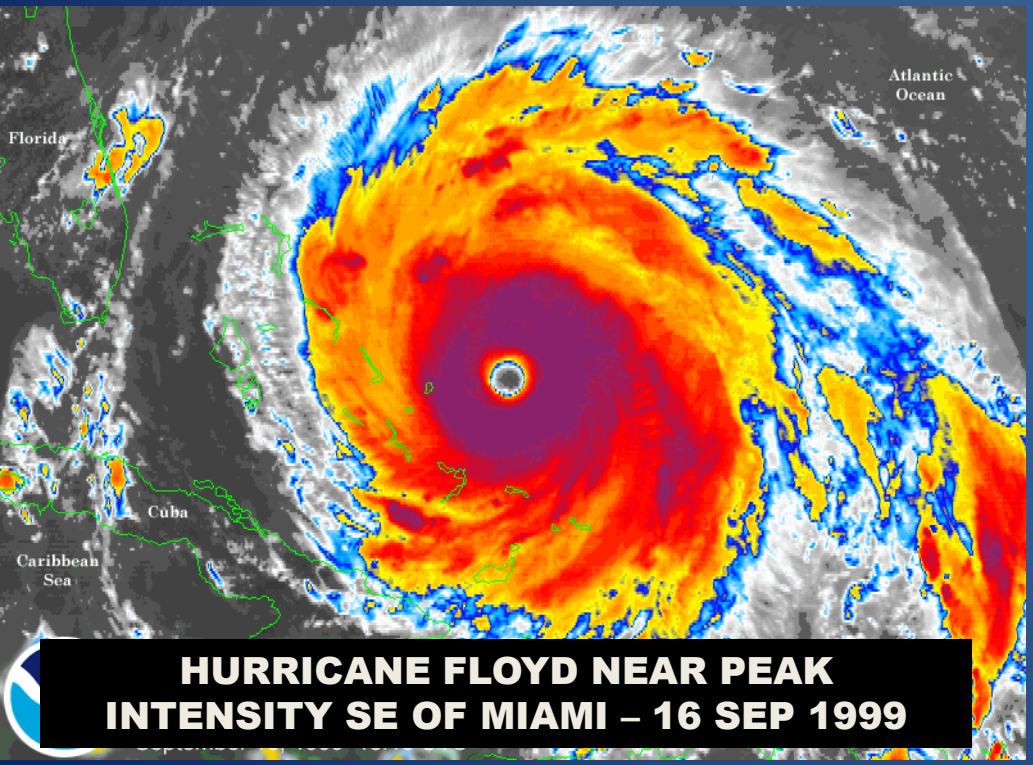
For a typical storm, the jet stream, and warm vs. cold air drive intensity



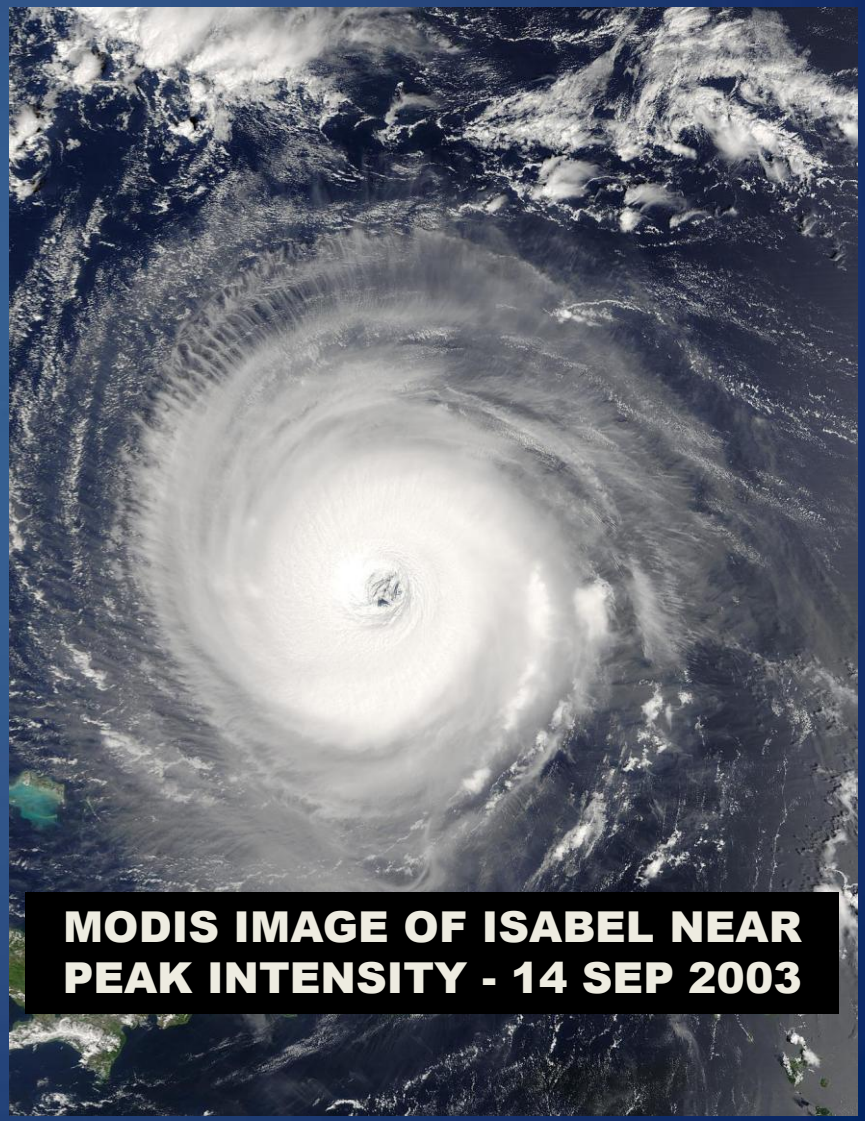
For tropical systems, warm ocean water and weak winds aloft are key factors

Hurricanes – The Basics

Hurricanes From a Satellite Perspective



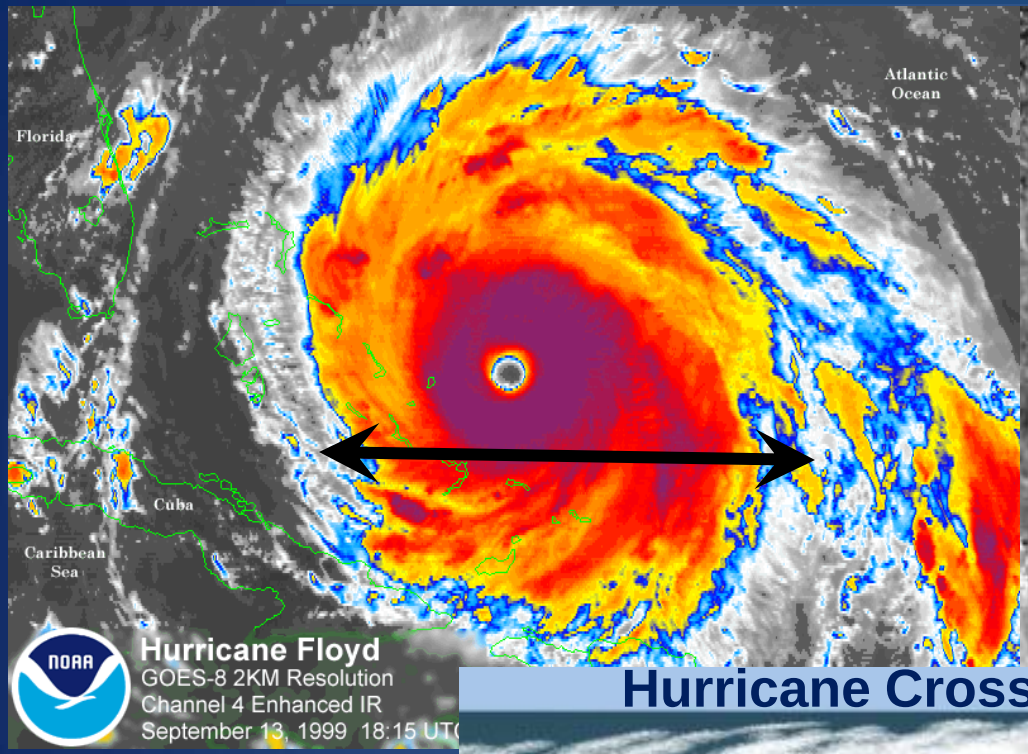
HURRICANE FLOYD NEAR PEAK INTENSITY SE OF MIAMI – 16 SEP 1999

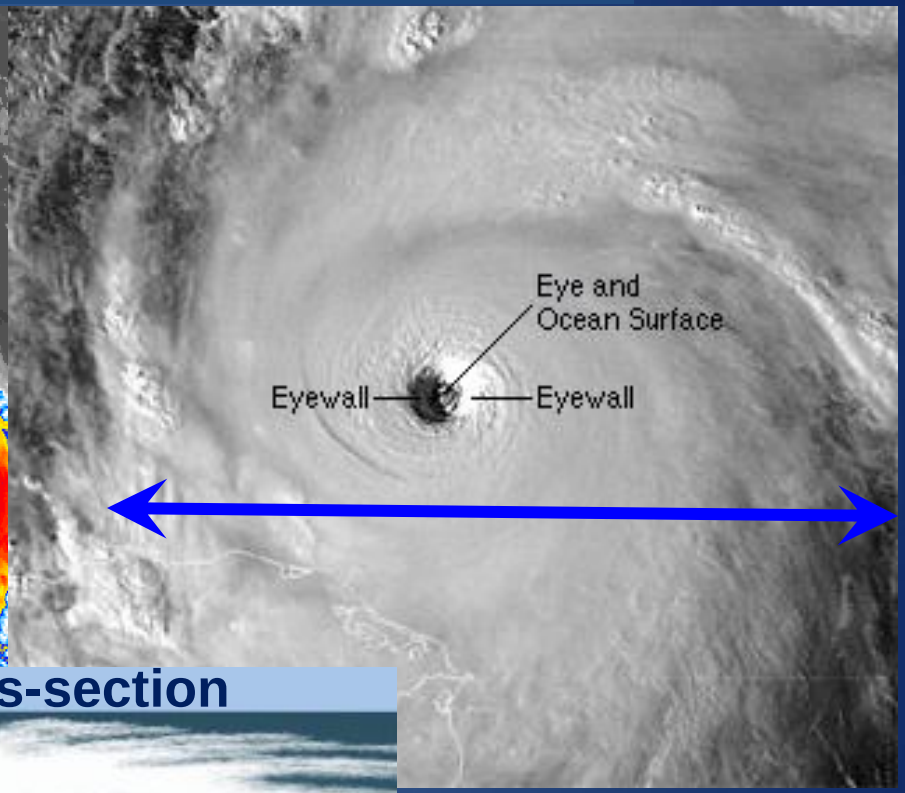


MODIS IMAGE OF ISABEL NEAR PEAK INTENSITY - 14 SEP 2003

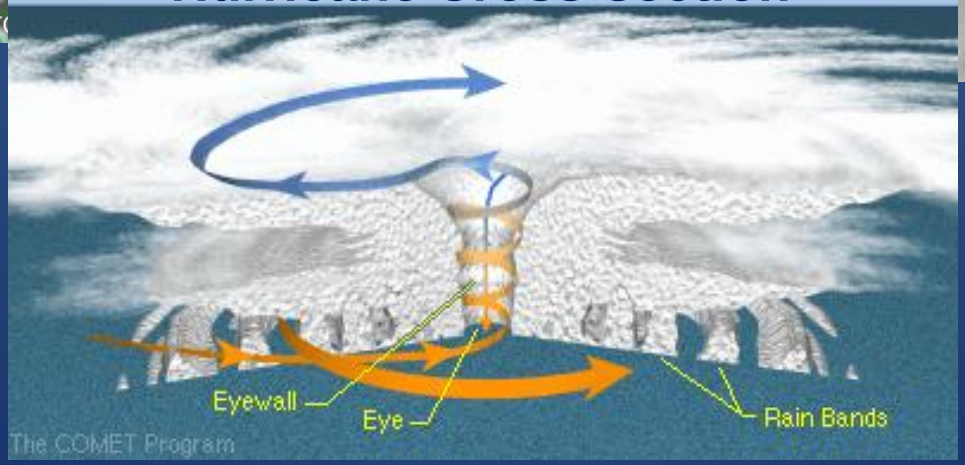
Hurricane Structure

Hurricanes as seen from satellite

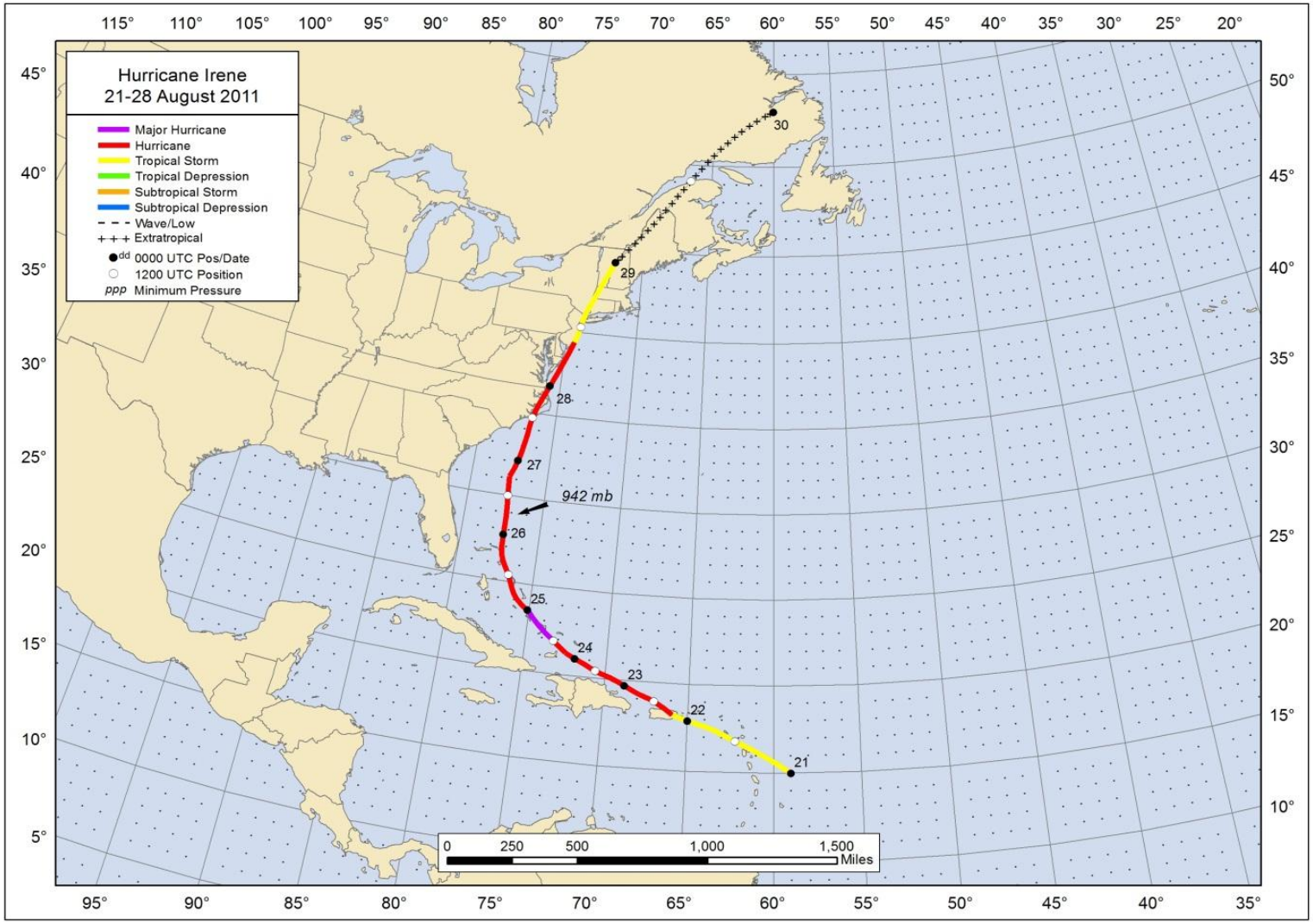




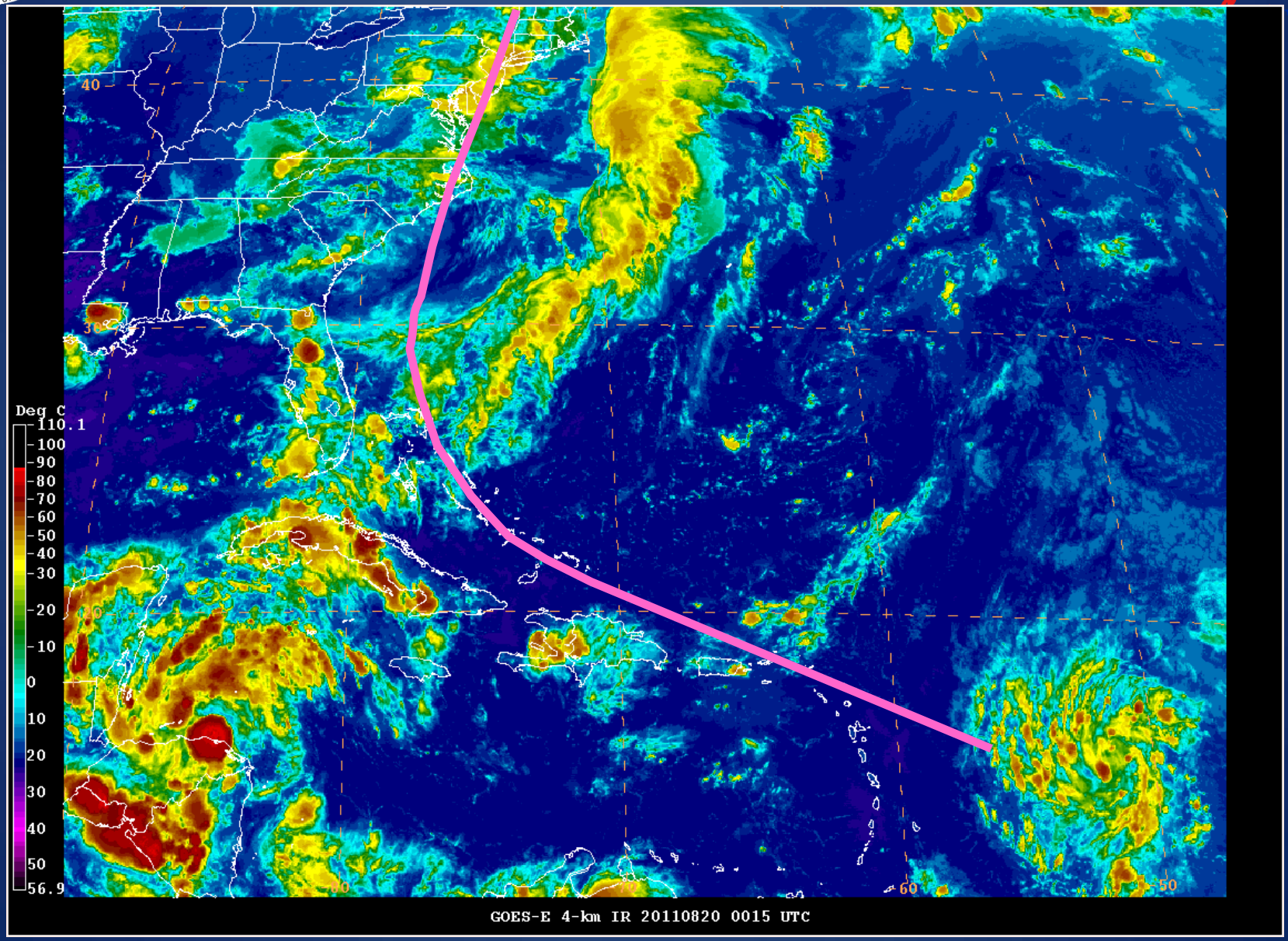
Hurricane Cross-section



Hurricane Irene (2011)



Hurricane Irene (2011)



Hurricane Intensity – Saffir-Simpson Scale

Saffir-Simpson Hurricane Scale		
Category	Wind Speed	
	mph	knots
5	≥156	≥135
4	131-155	114-134
3	111-130	96-113
2	96-110	84-95
1	74-95	65-83
Non-Hurricane Classifications		
Tropical Storm	39-73	34-64
Tropical Depression	0-38	0-33

Image Courtesy: Watts Up With That

Original Saffir-Simpson Scale (1974)

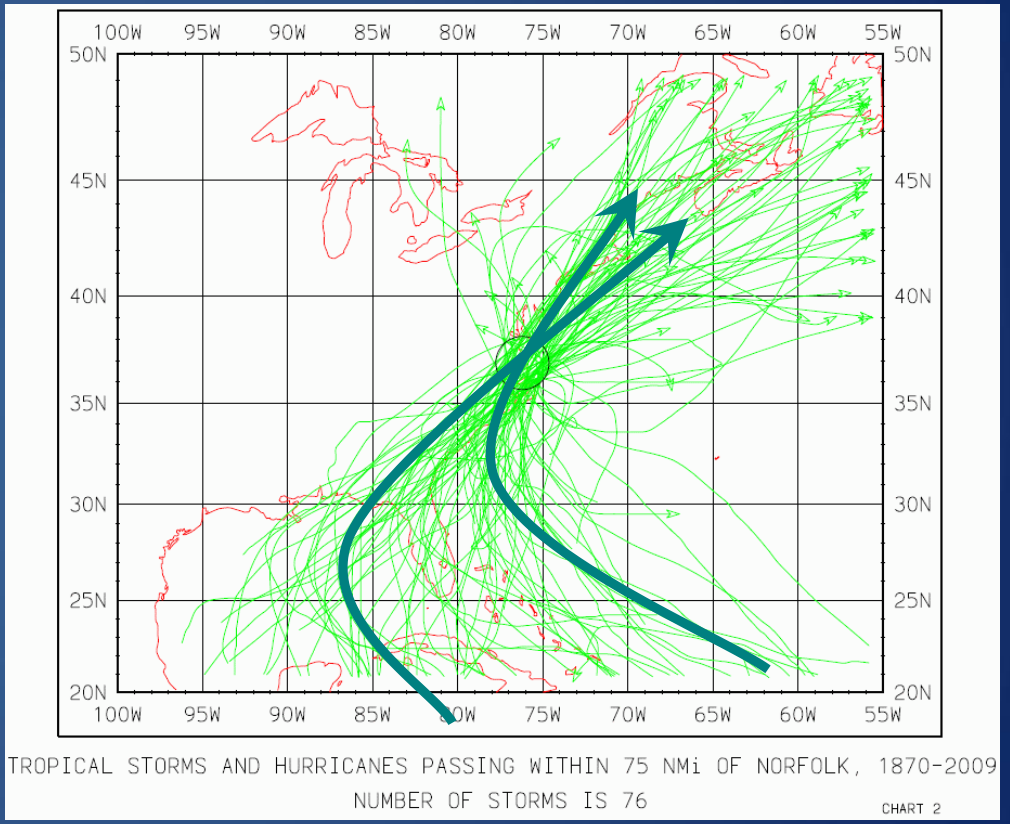
Table 1. Saffir/Simpson Hurricane Scale [Simpson, R.H. (1974)].

Scale Number (Category)	Central Pressure (Millibars)	Central Pressure (Inches)	Winds (Mph)	Surge (Feet)	Damage
1	>979	28.91	74-95	to	Minimal
2	965-979	28.50-28.91	96-110	6 8	Moderate
3	945-9	27 -28.47	111-130	2	Extensive
4	92 944	27.17- 88	131-155	3 to	Extreme
5	< 920	< 27.17	> 155	> 18	Catastrophic

Wind, Surge, Pressure Relationships Failed for Isabel (2003), Katrina (2005), Ike (2008), etc.

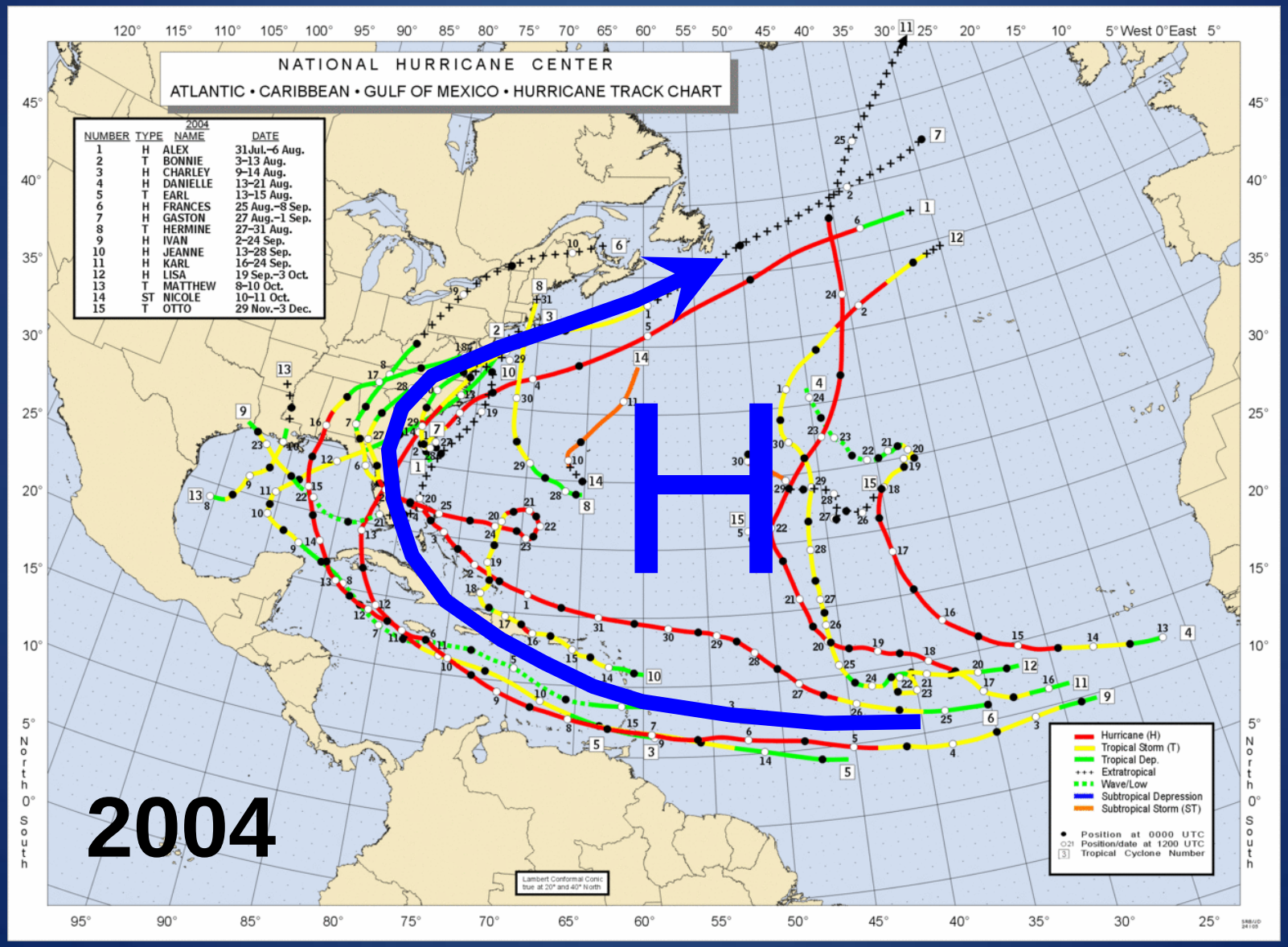
Hurricane Movement

- Two Primary Factors
  - Location and westward extent of the "Bermuda" or Subtropical High Pressure area at Upper Levels
  - Location and Shape of the Jet Stream (Hatteras northward)

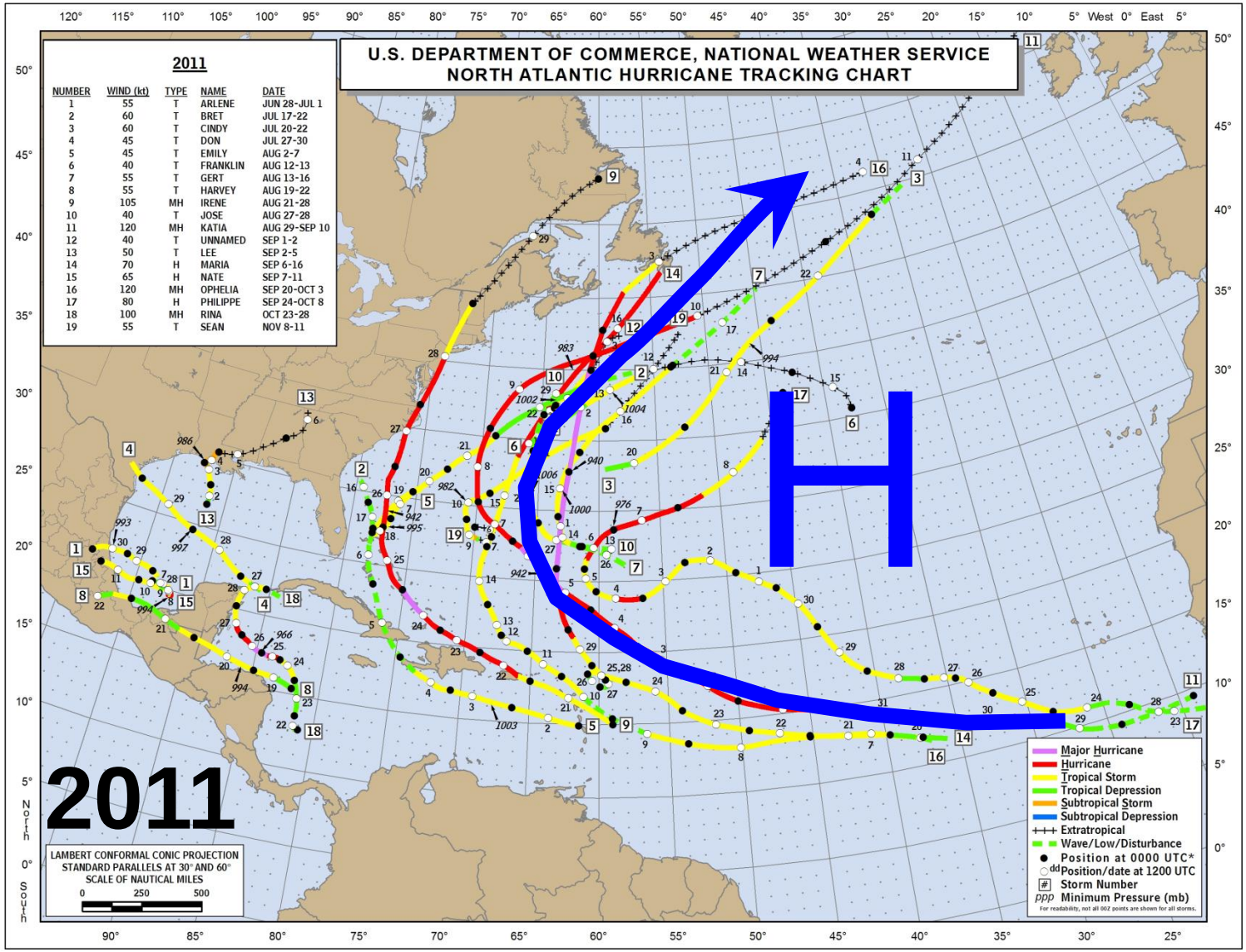


All Tropical Cyclones

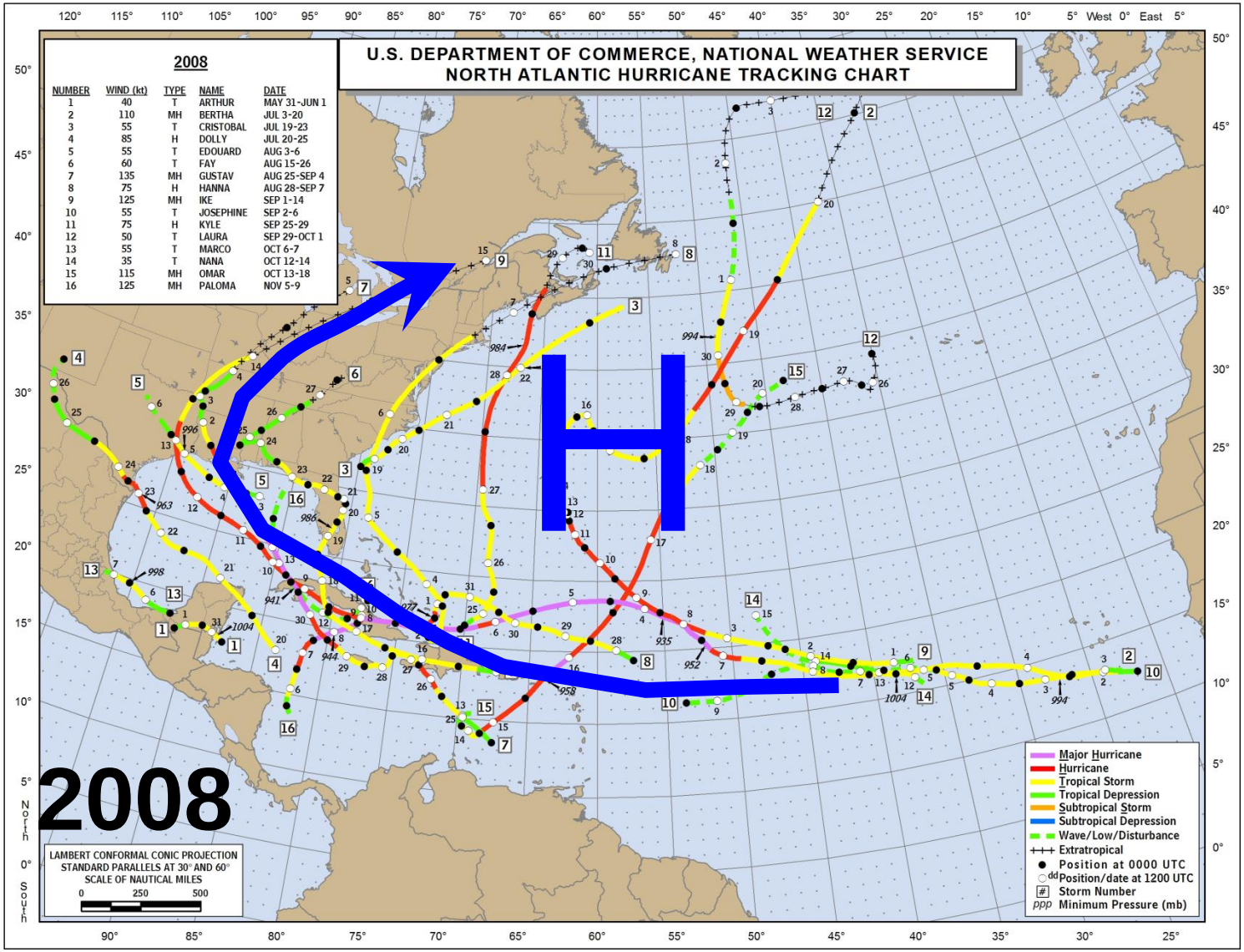
Some Seasonal Examples



Some Seasonal Examples



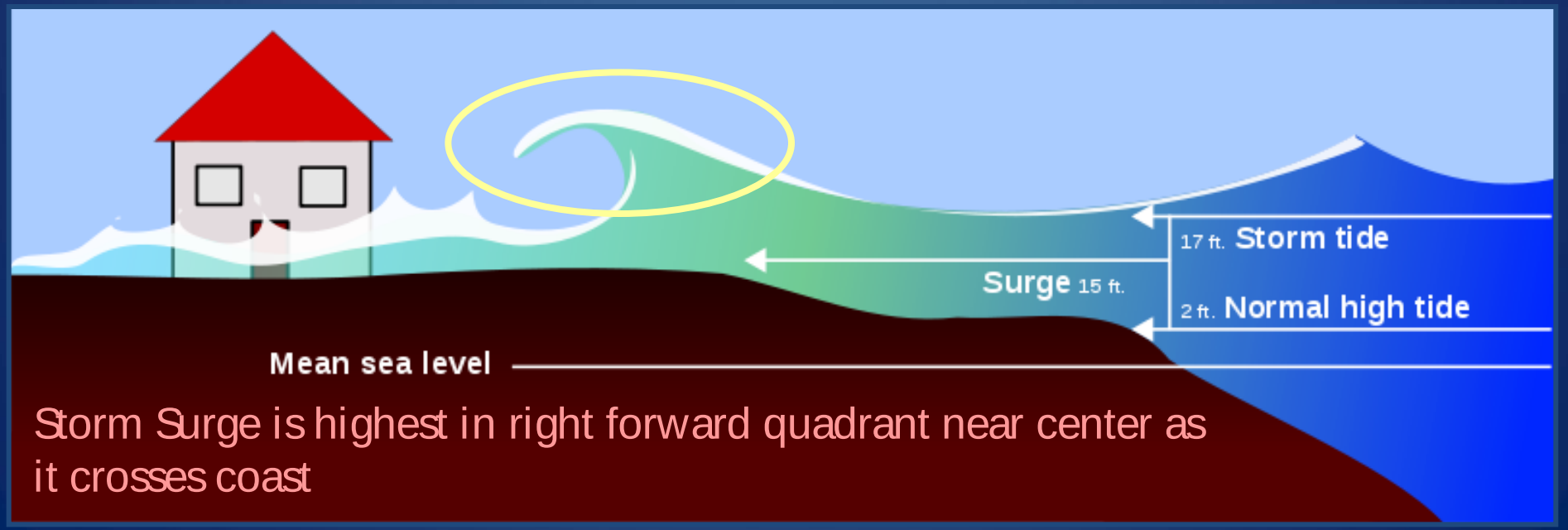
Some Seasonal Examples



Hurricane Impacts

STORM SURGE – The abnormal rise in water level directly associated with the wind and pressure forces associated with a hurricane

Storm Surge Example – hurricane makes landfall at high tide

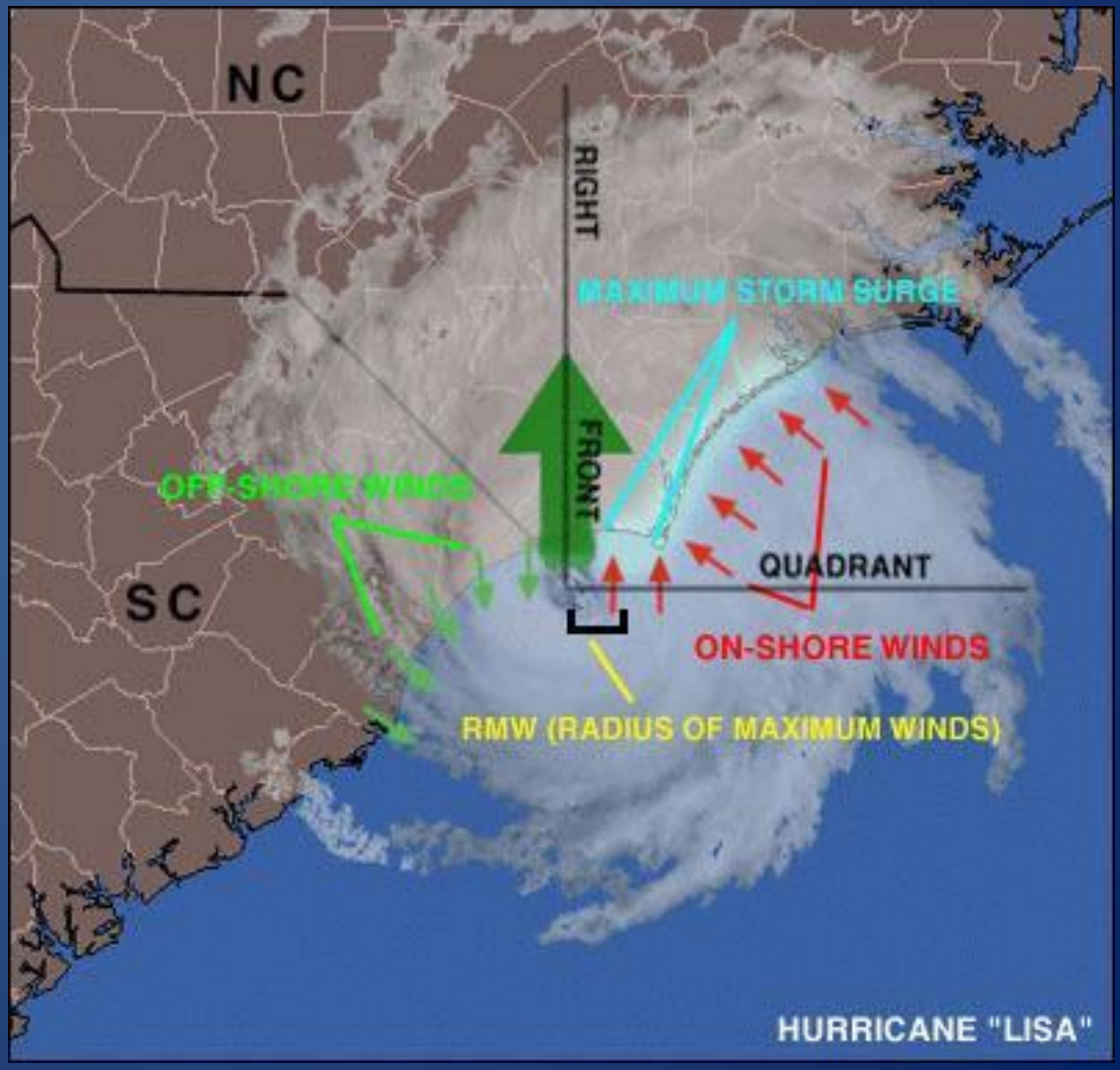


Storm Surge is highest in right forward quadrant near center as it crosses coast

Hurricane Impacts

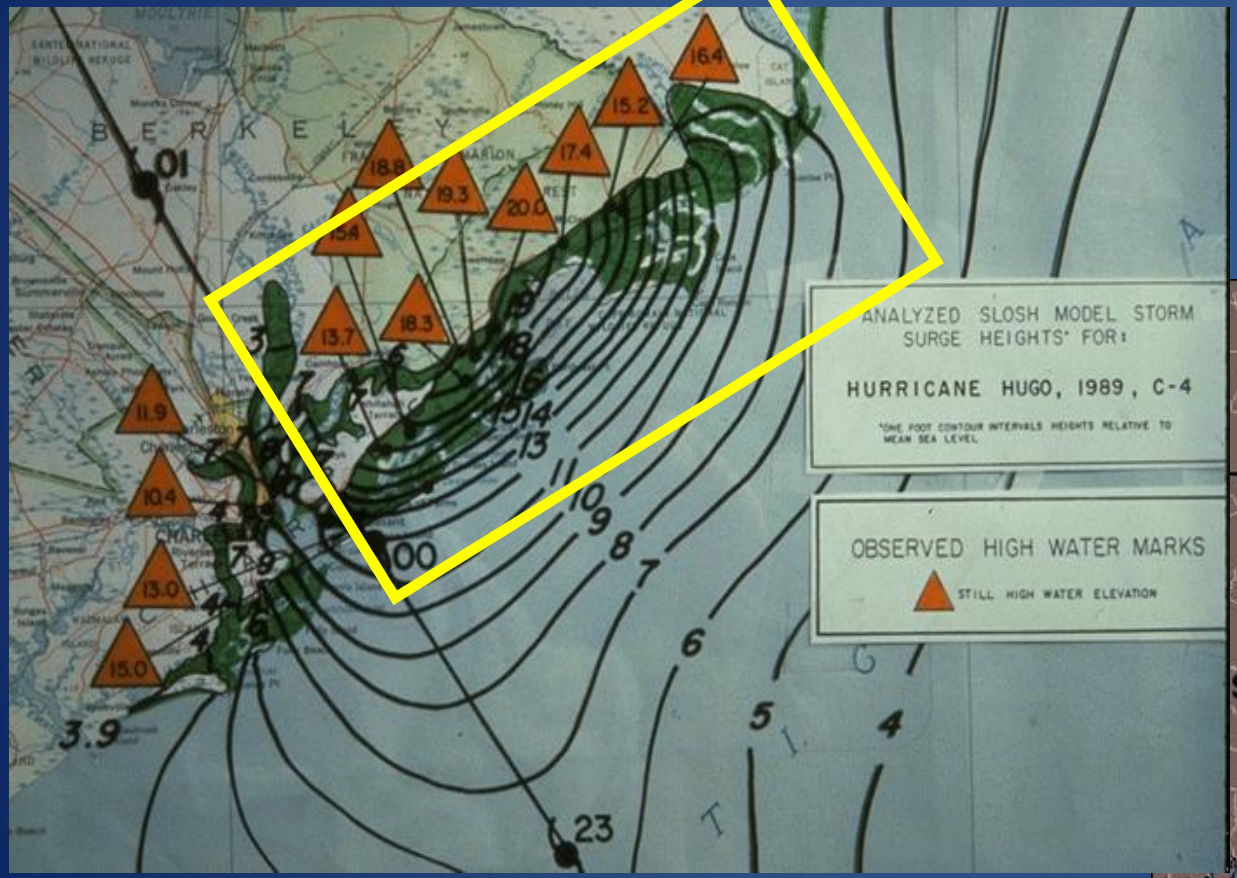
Storm Surge

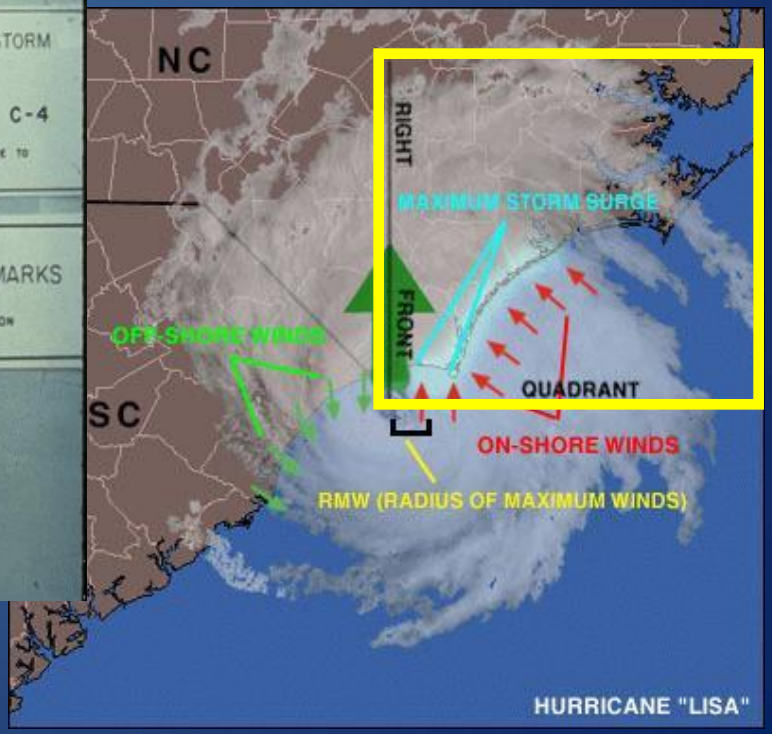
Storm Surge is highest and Winds are greatest in the RIGHT FORWARD QUADRANT close to where center makes landfall



Storm Surge Contd.

Storm Surge Example – Hugo 1989

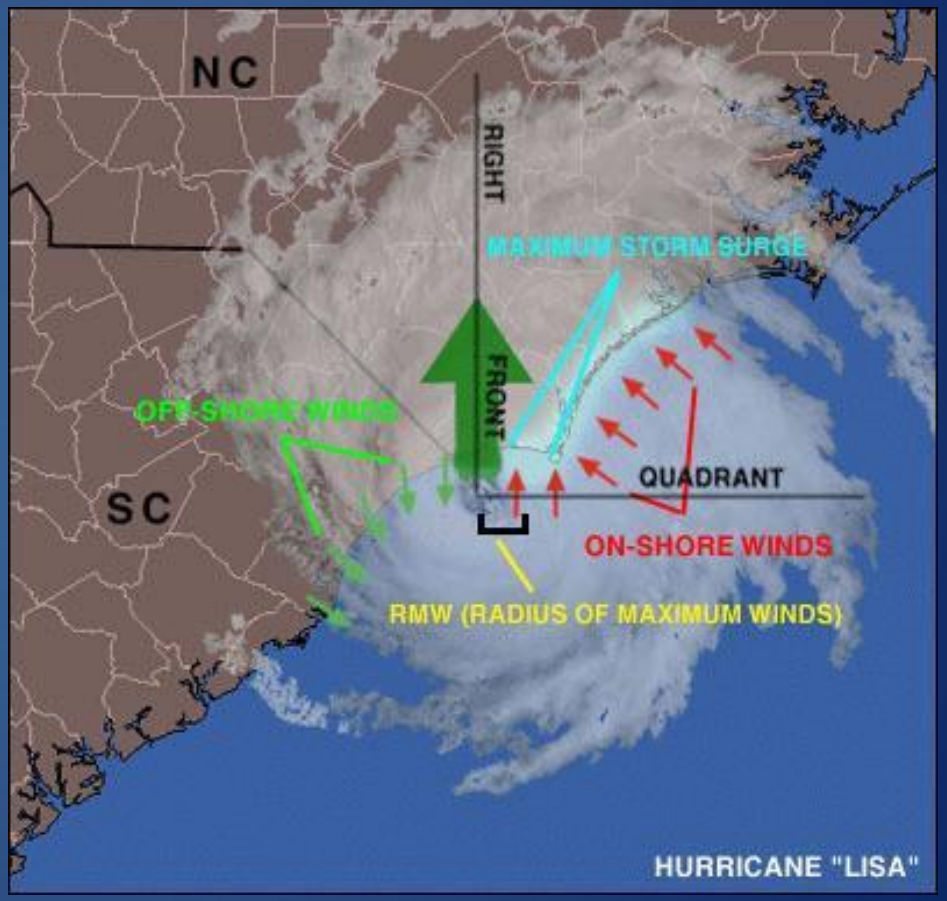




Storm Surge

Storm Surge Factors

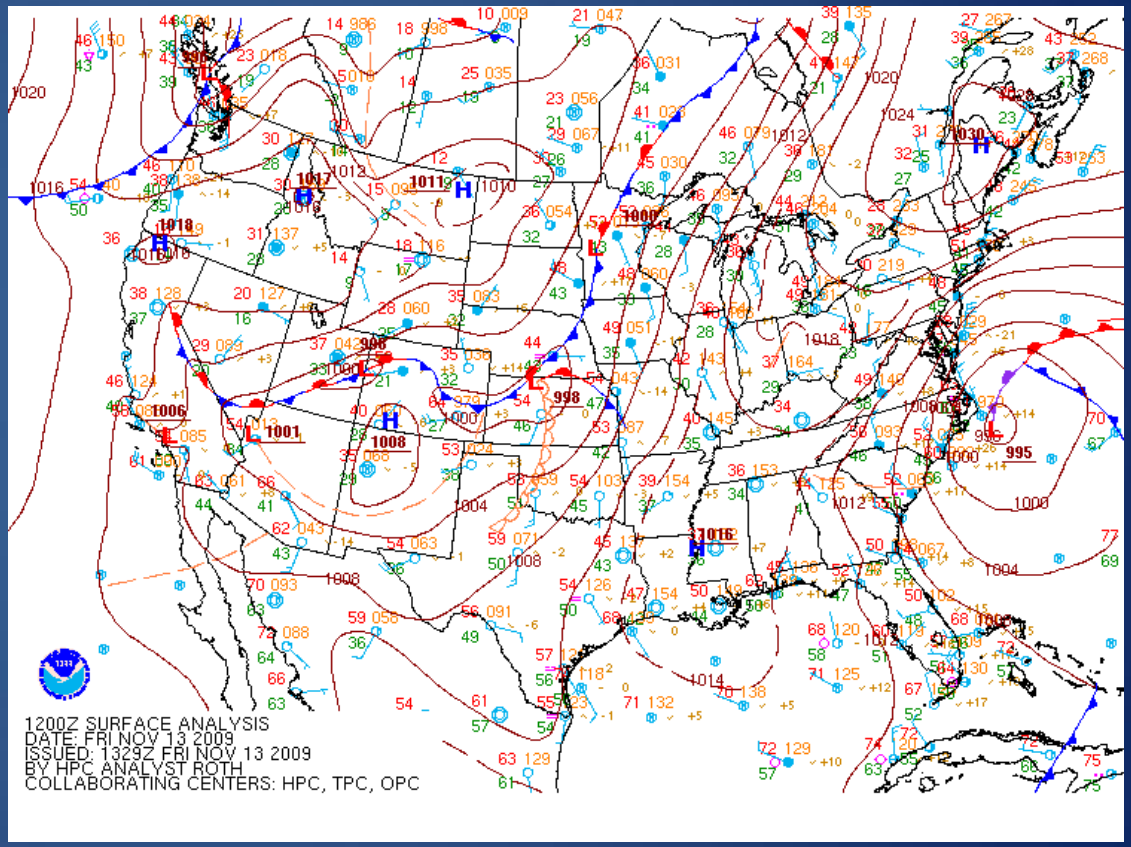
- Storm Intensity and Size
  - Stronger = Higher Surge
  - Larger = Larger Area Affected
- Storm Speed
  - Slower Often Means Higher Surge
- Angle to Coast at Landfall
  - Perpendicular Maximizes Surge (Katrina)



Nor'Easter Coastal Flooding

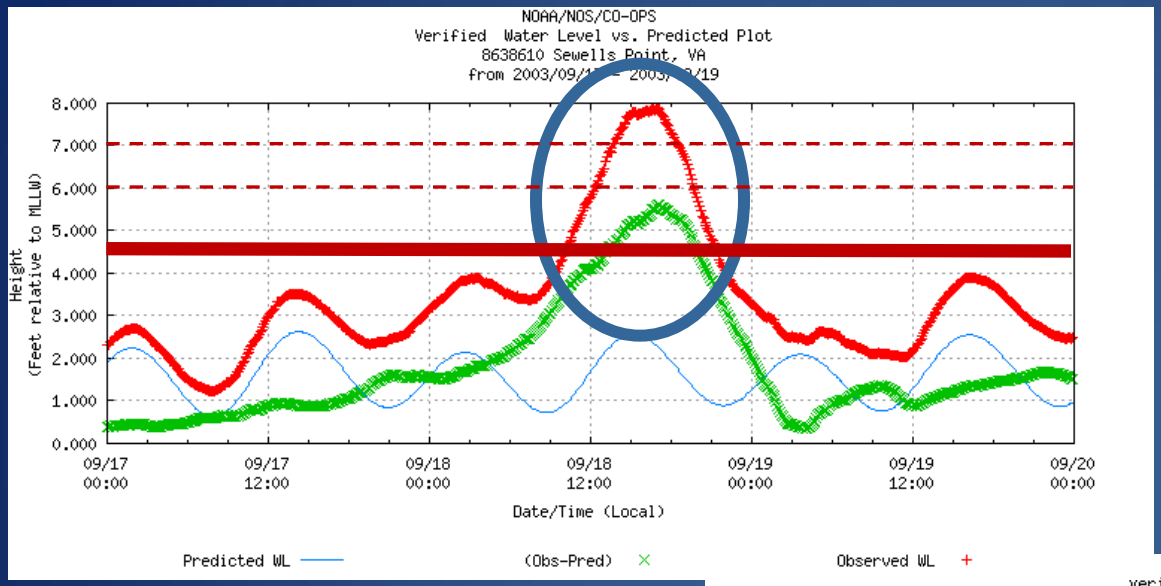
- Wind Direction, Wind Speed and Duration of Strongest Wind Most Important
  - N/NNE Winds ≥ 25-30mph
- Storm Track/Intensity not as Critical

November, 2009 "Nor' Ida" Nor'easter



Storm Surge

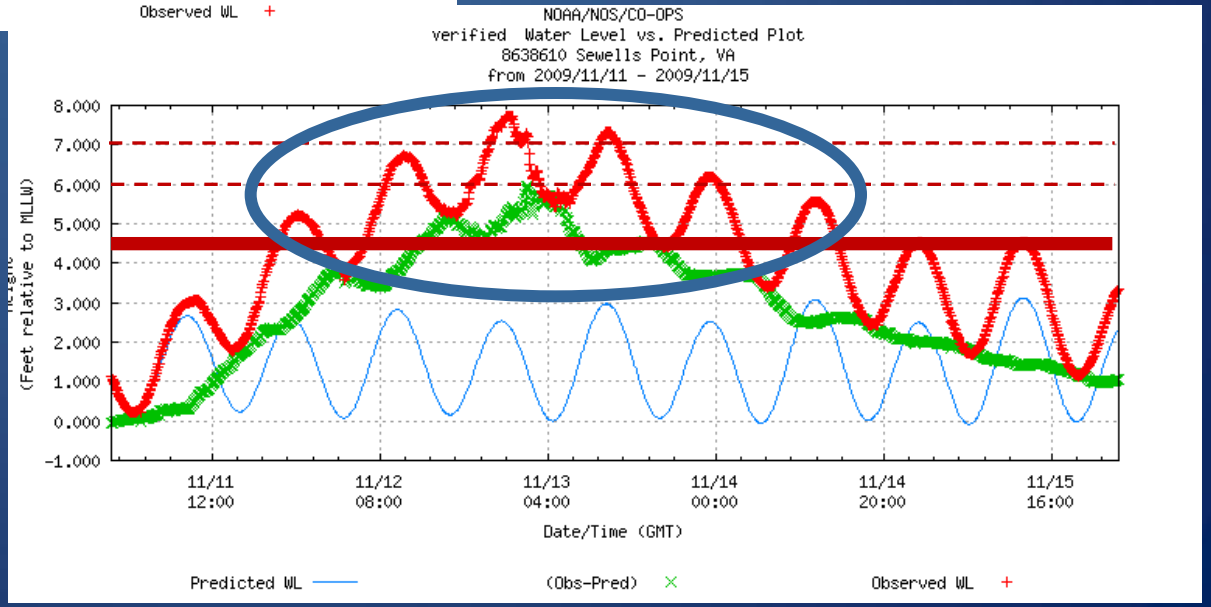
Hurricanes vs. Nor'easters



Minor Flooding Begins

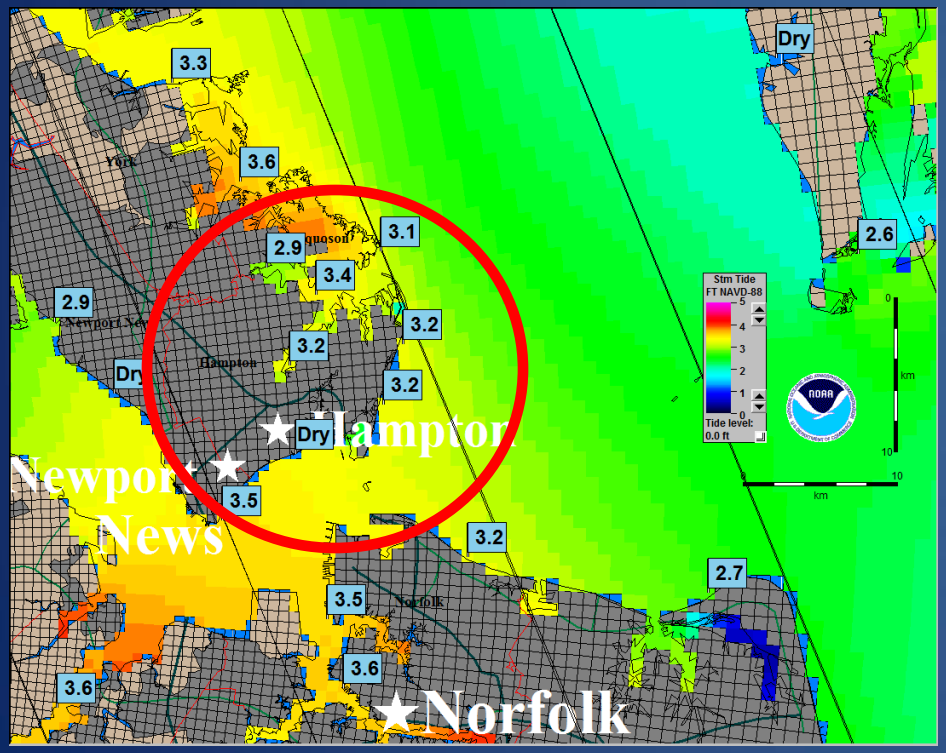
Sewells Point - Isabel

Sewells Point
11/2009 Nor'easter

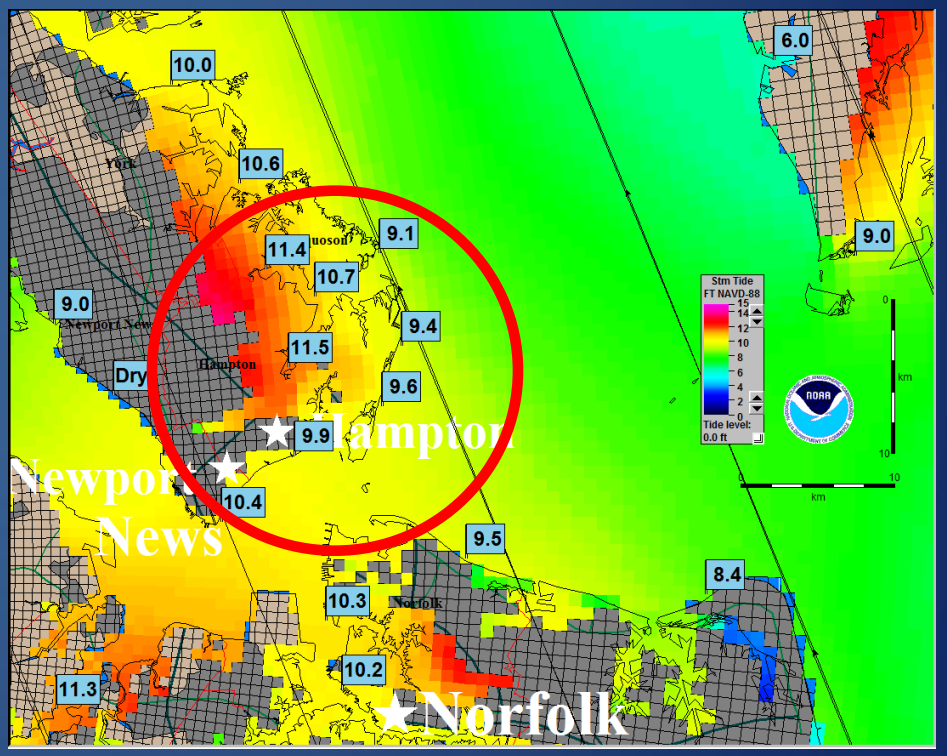


Storm Surge Example

FACTOR = STORM INTENSITY



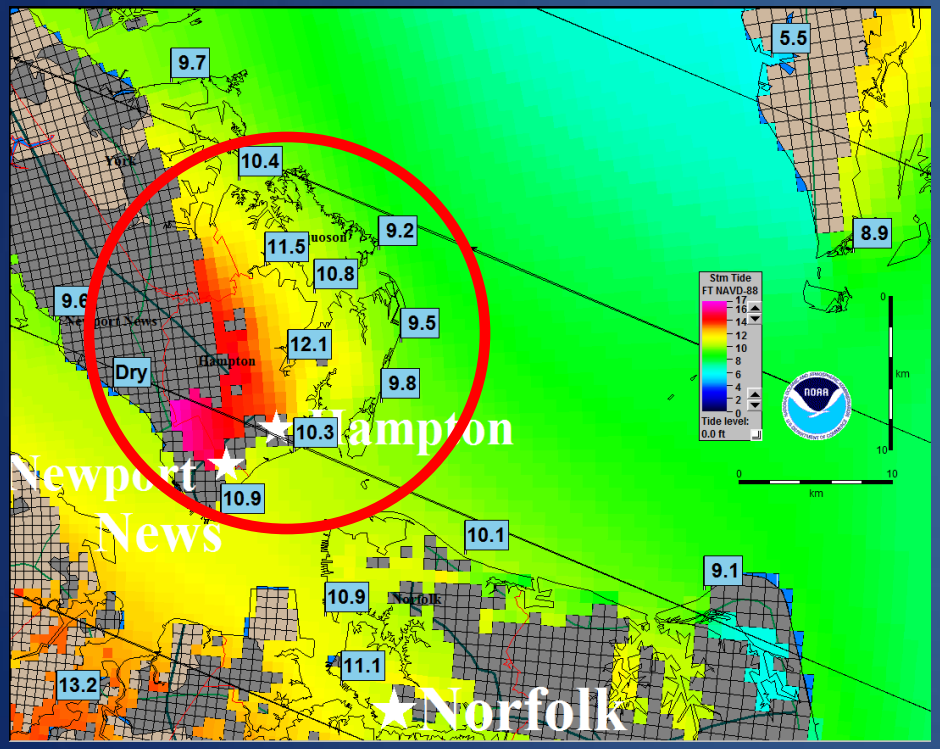
CAT 1 NNW 20 mph



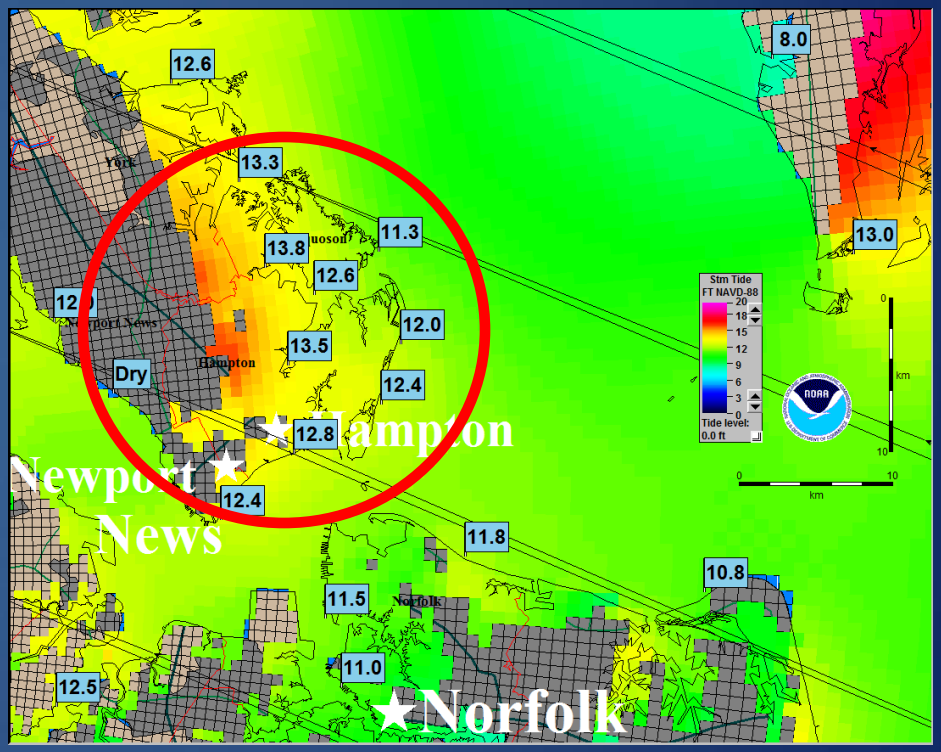
CAT 3 NNW 20 mph

Storm Surge Example

FACTOR = STORM SPEED



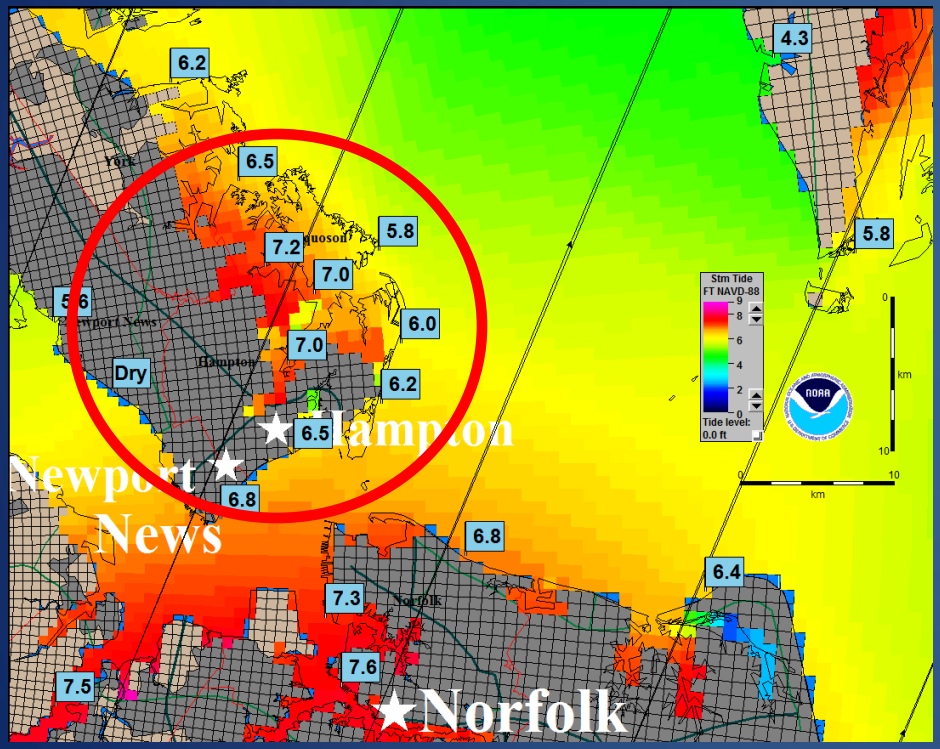
CAT 3 WNW 10 mph



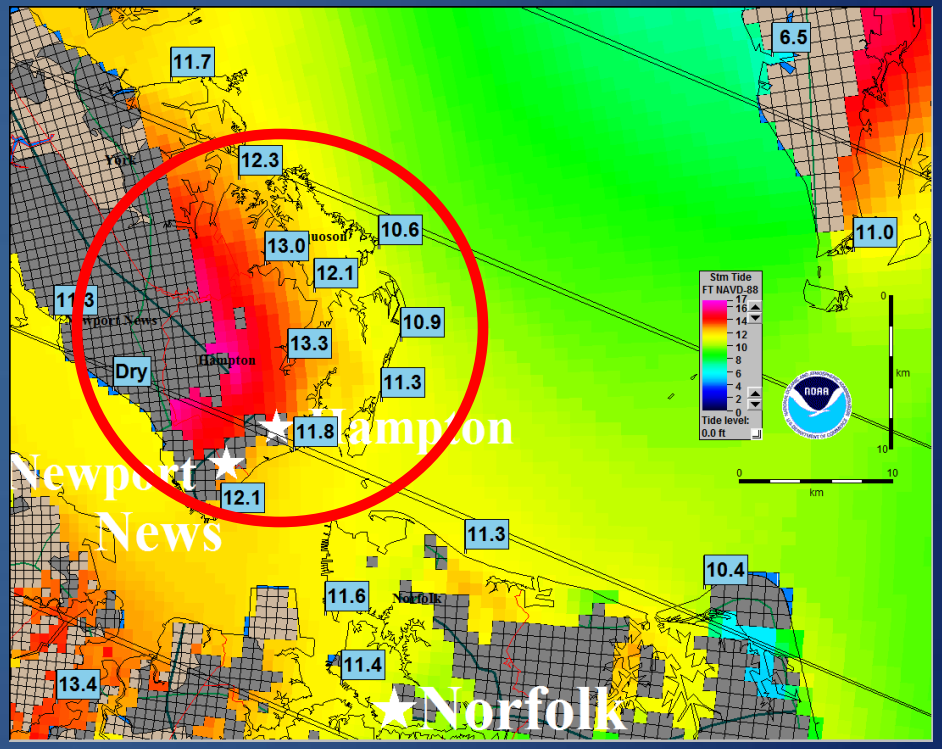
CAT 3 WNW 30 mph

Storm Surge Example

FACTOR = ANGLE TO COAST



CAT 3 NNE 20 mph



CAT 3 WNW 20 mph

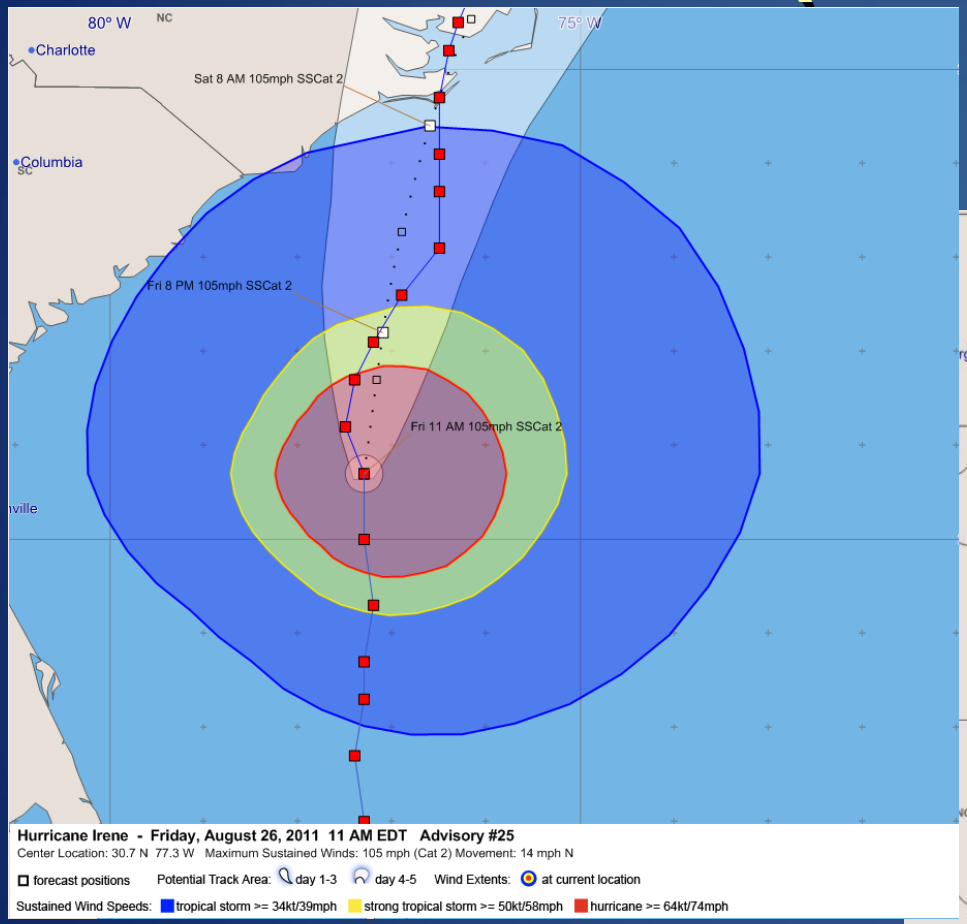
Hurricane Impacts

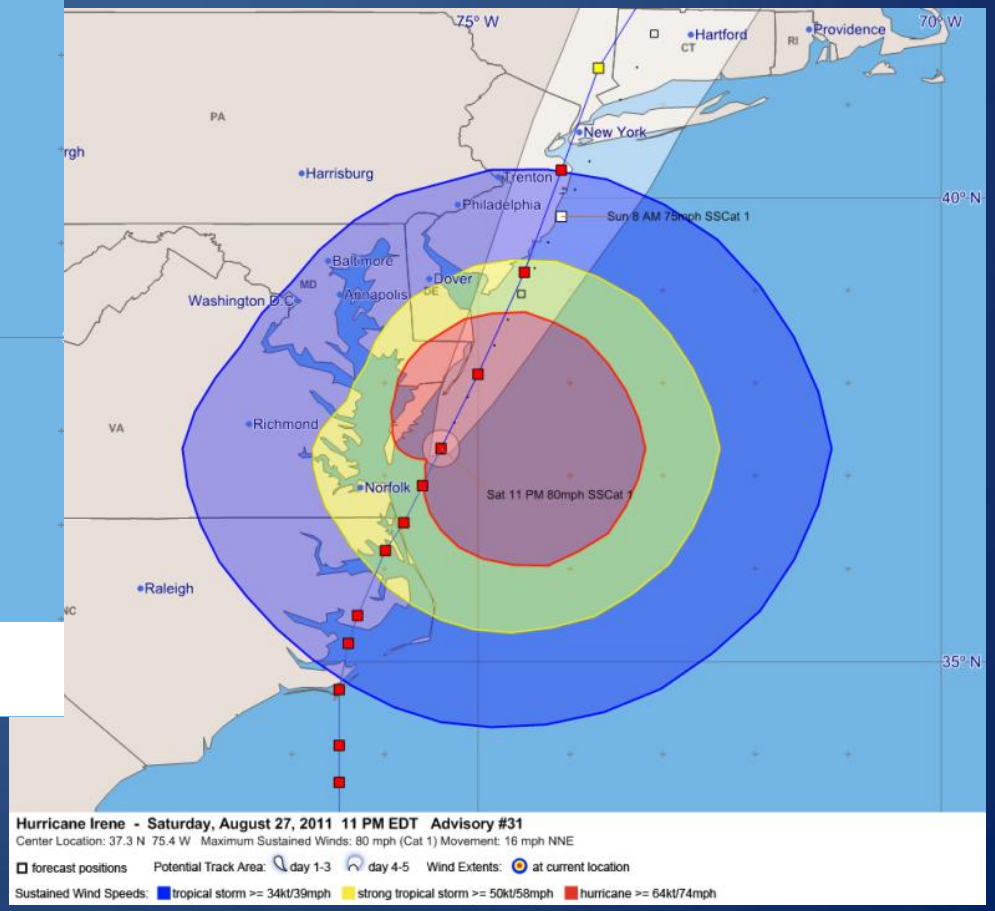
Wind

- Pre-Landfall
  - Winds often Symmetrical Around Center
- Post-Landfall
  - **Winds Always Weaken After Landfall**
    - Cat 3 at Landfall -> Cat 2 or less within 6 hours
  - Winds Stronger Eastern Semi-Circle (Right Side)
    - Especially if Storm is in Close Proximity to Water

Hurricane Impacts

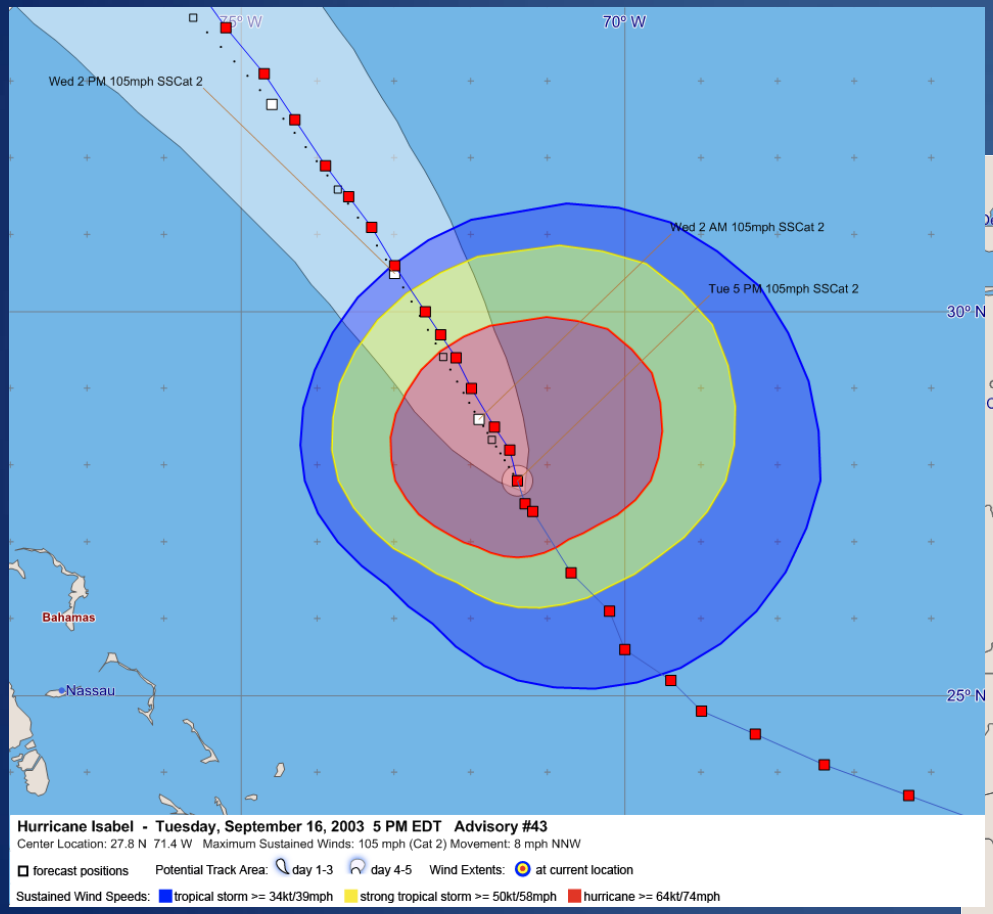
Wind (Irene – 2011)

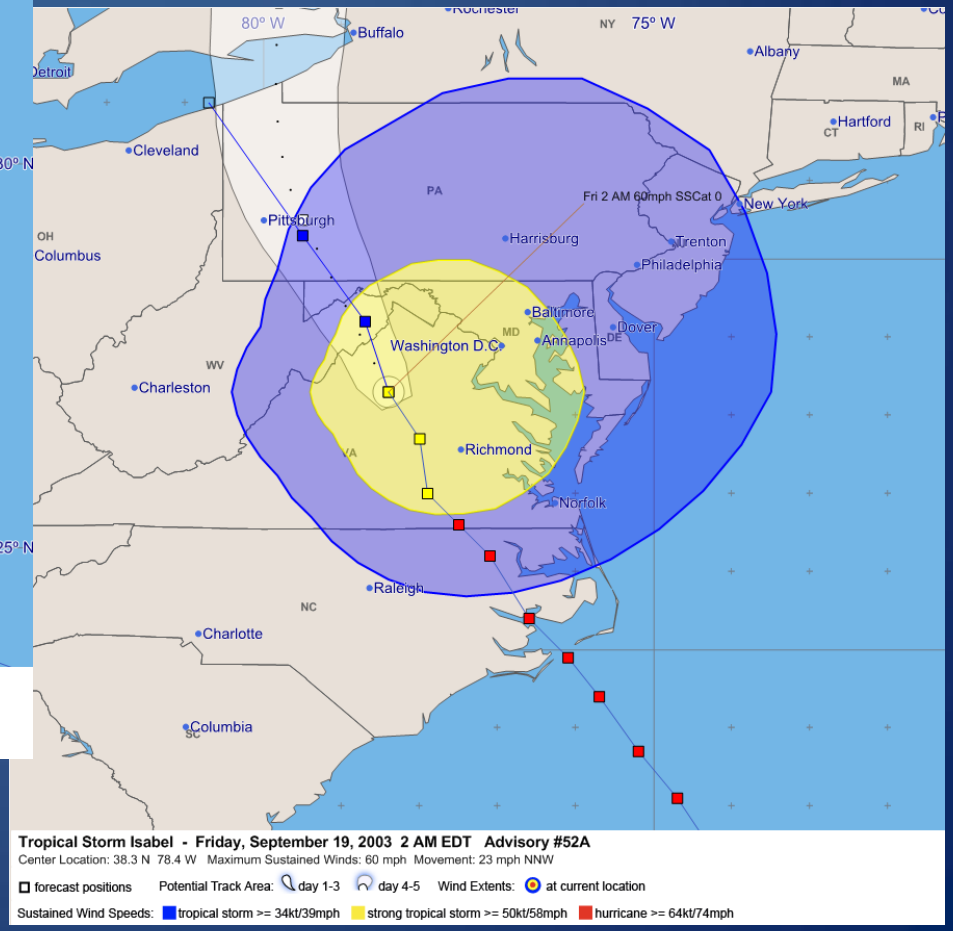




Hurricane Impacts

Wind (Isabel - 2003)

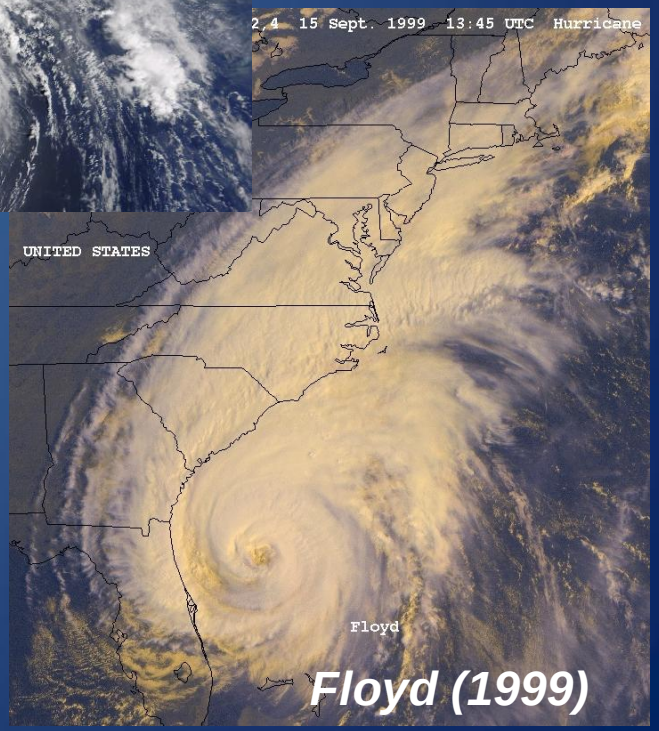




Hurricane Impacts

Rainfall and Fresh Water Flooding

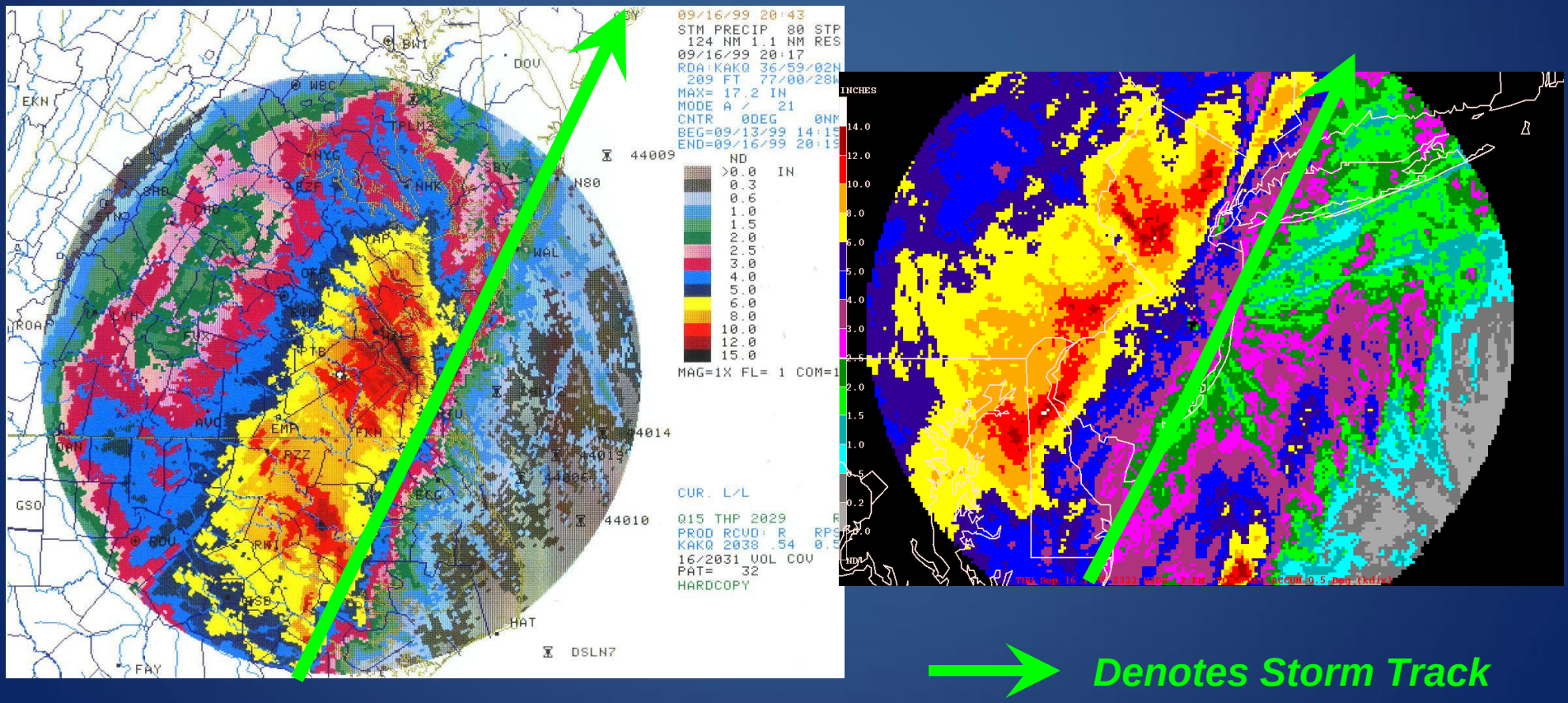
- At Landfall – Rainfall is often Uniformly Distributed Around the Storm, Especially a well Developed Hurricane
- Post-Landfall – Rainfall Pattern often shifts to the LEFT of the Storm Track, as dry air Entrains South/East of the center.



Hurricane Impacts

Rainfall and Fresh Water Flooding

Hurricane Floyd (1999) Rainfall Pattern vs. Storm Track

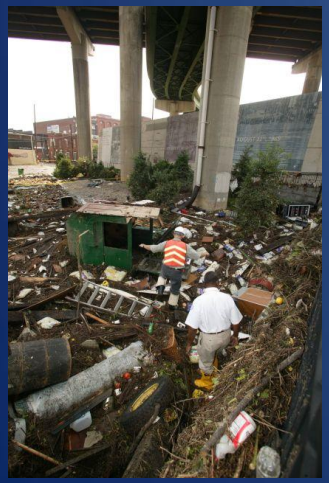


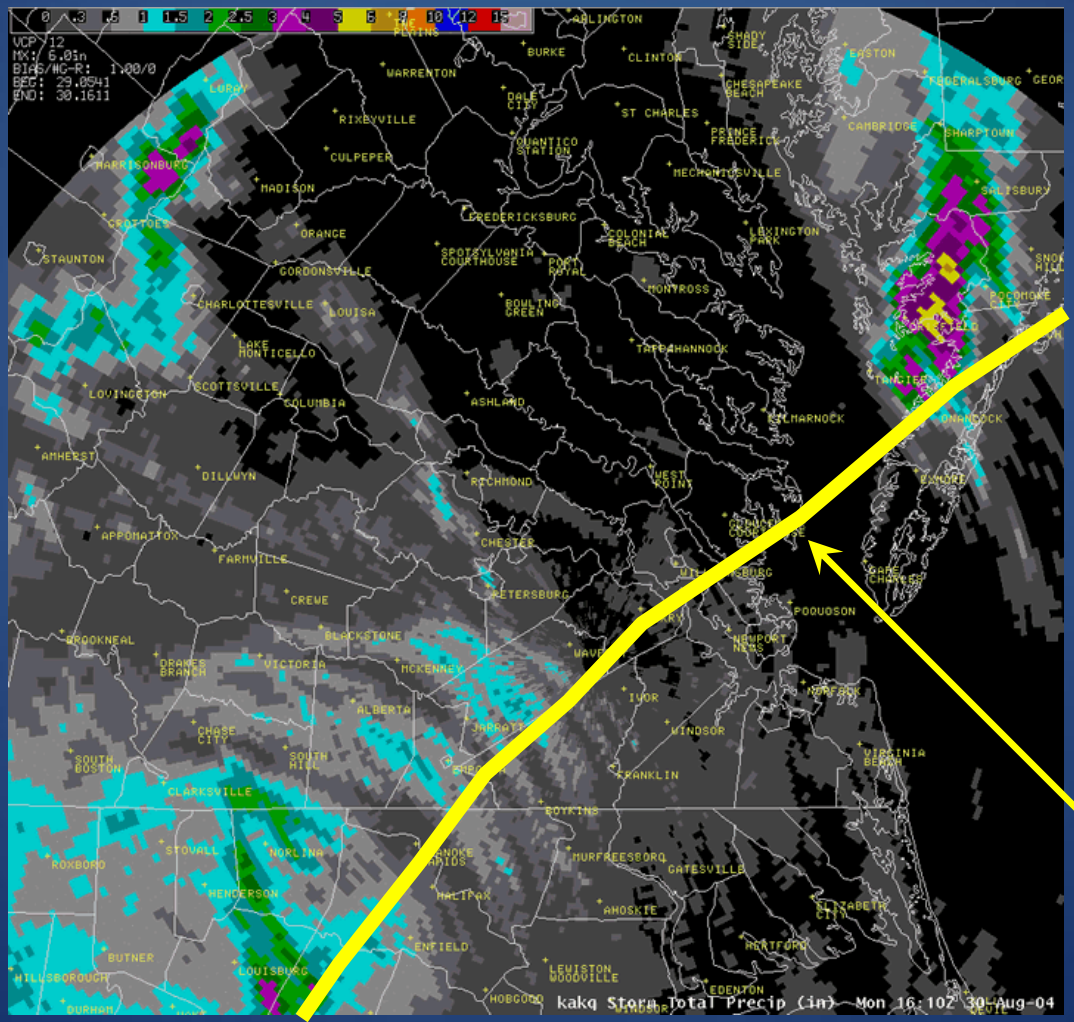
Denotes Storm Track

Hurricane Impacts

Rainfall and Fresh Water Flooding

TS Gaston (2004)



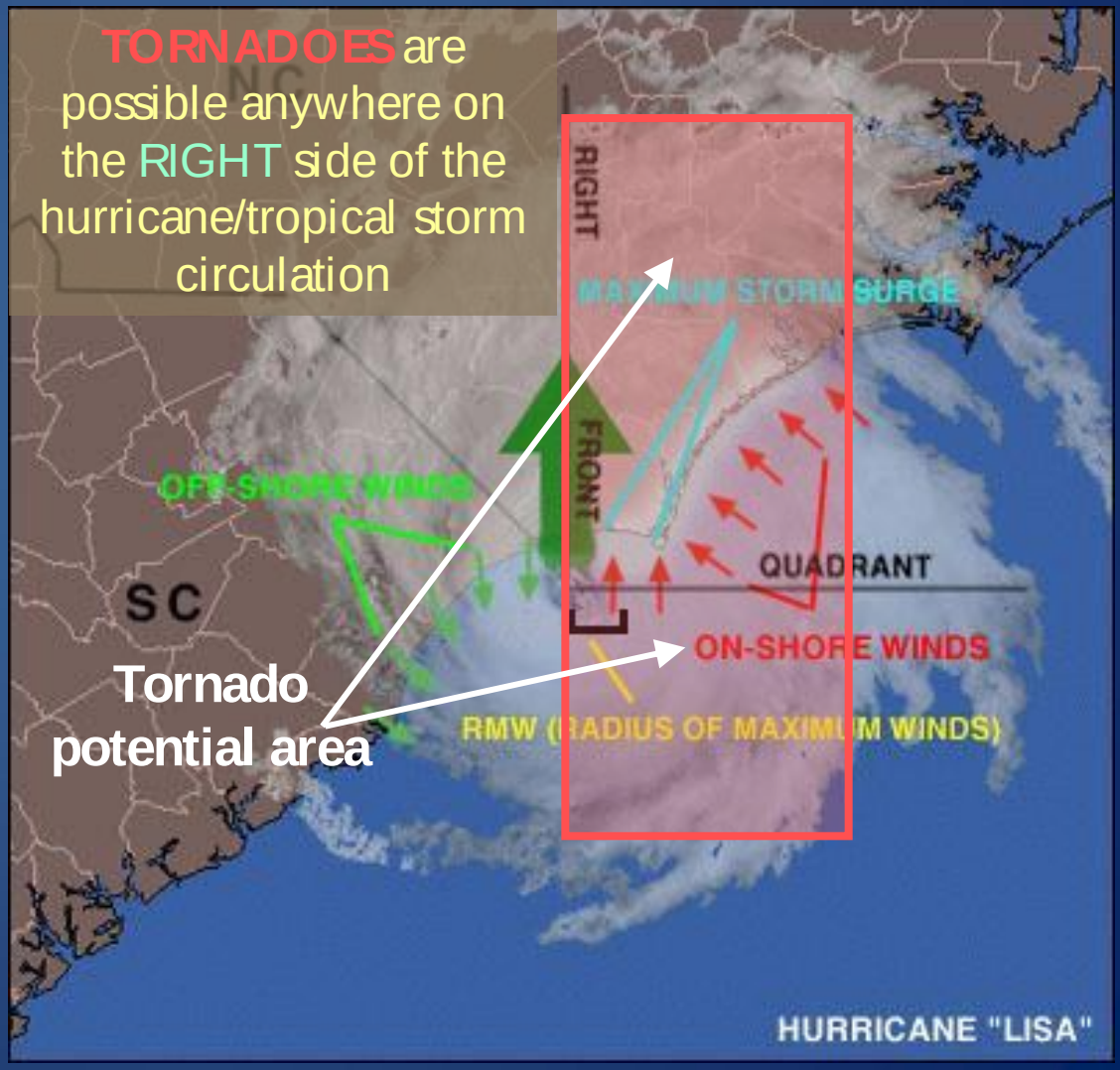


Storm Track

Hurricane Impacts

Tornadoes

Some tropical systems (Bertha, 1996, and Gaston, Frances, and Ivan in 2004) are prolific tornado producers, other (Fran, 1996 and Isabel, 2003) produce few or none.



Hurricane Impacts

Tornadoes

All Tropical Cyclones

Hurricanes

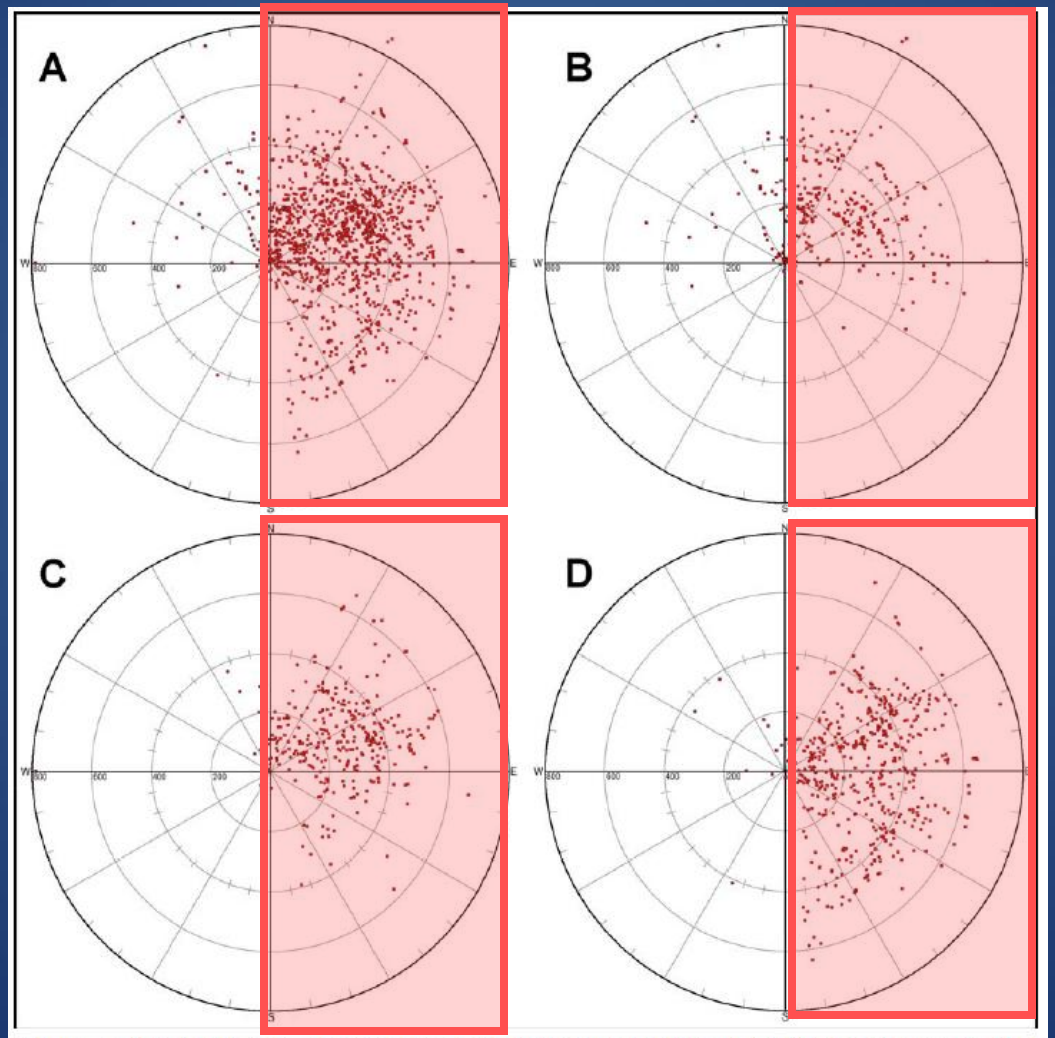


Figure 4. Cartesian plot of U.S. TC tornado reports (red dots) from: a) all TCs 1995-2009; b) hurricanes; c) tropical storms; and d) tropical depressions and post-classification categories "N" as defined in the text. Range rings at 200-km intervals, radials at 30° intervals. Origin represents interpolated center position of TC or remnant low.

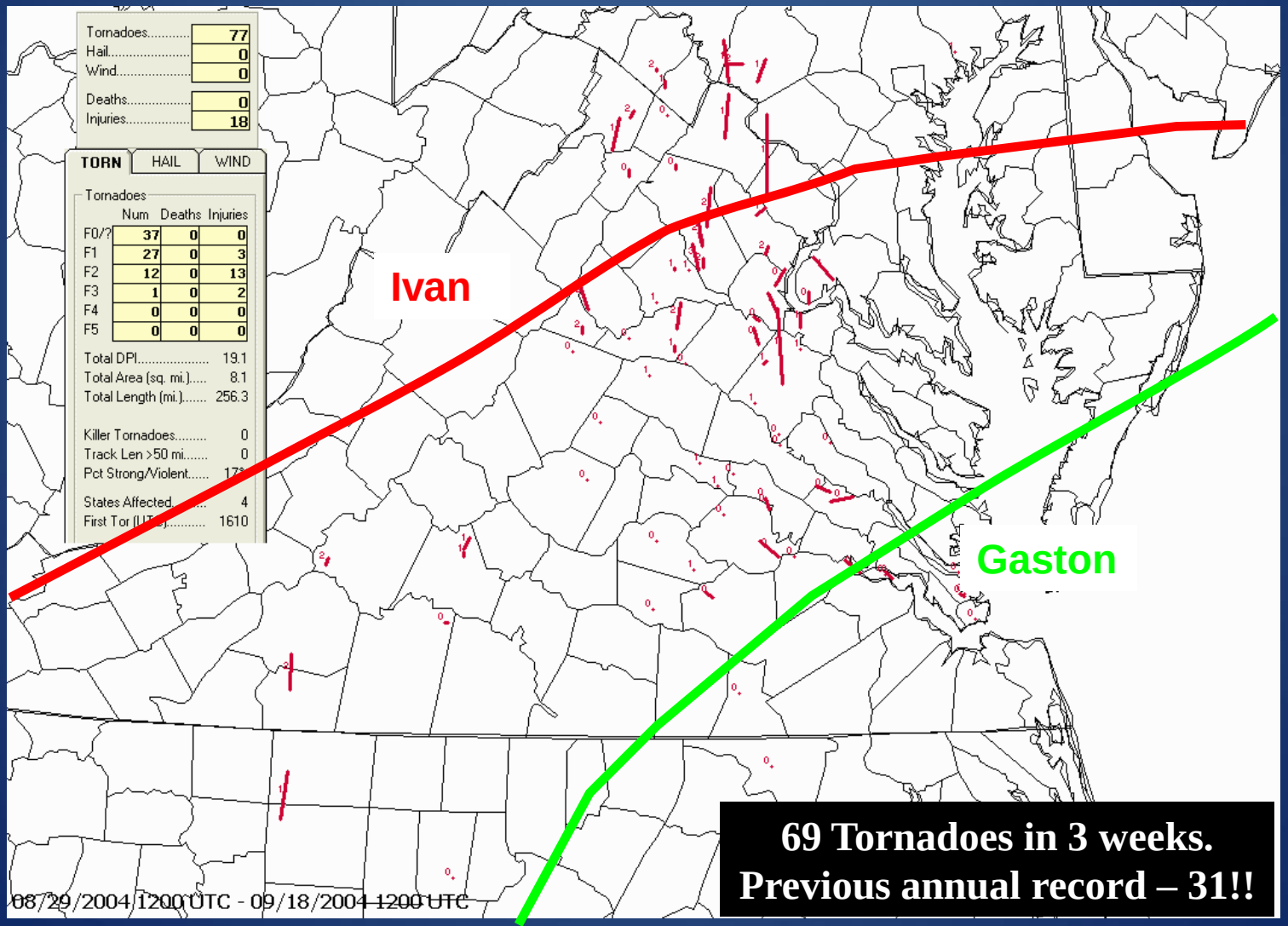
Tropical Storm

Tropical Depression

From: Edwards (2011)

Hurricane Impacts

Tropical Tornadoes 2004



Hurricane Resources

- National Hurricane Center
  - http://hurricanes.gov
- NWS Wakefield Briefing Web Page
  - http://www.erh.noaa.gov/akq/empage.php
- NWS Wakefield Storm Specific Page
  - http://www.erh.noaa.gov/akq/brief/Stormname.php
- Probabilistic Storm Surge/Surge Inundation Graphics
  - http://www.nws.noaa.gov/mdl/psurge2.0/

The End!!

Are There Any Additional Questions?

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